2000

An Assessment of on-line package customization for sheet size products packaged in paperboard envelopes

Kevin Kennedy

An Assessment of On-Line Package Customization for Sheet Size Products Packaged in Paperboard Envelopes

By

Kevin T. Kennedy

A Thesis

Submitted to the Department of Packaging Science,
College of Applied Science and Technology
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Rochester Institute of Technology

2000

Department of Packaging Science
College of Applied Science and Technology
Rochester Institute of Technology
Rochester, New York

Certificate of Approval

M.S. DEGREE THESIS

The M.S. Degree Thesis of Kevin T. Kennedy
has been examined and approved
by the thesis committee as satisfactory
for the thesis Requirements for the Master of Science Degree.

Gary Schum

Thomas Kausch

Dan Goodwin

December 14, 1999

An Assessment of On-Line Package Customization
for Sheet Size Products Packaged in Paperboard Envelopes

I, Kevin T. Kennedy, prefer to be contacted each time a request for reproduction is made. If permission is granted, any reproduction will not be for commercial use or profit. I can be reached at the following address

Kevin T. Kennedy
151 Hillside Drive
Hilton, New York 14468
Phone: (716) 392-6944

May 1, 2000

Acknowledgements

I would like to express my appreciation to everyone who helped me to carry out my research and organize the results in this thesis. I'd like to thank The Eastman Kodak Company and particularly the Package Engineering and Graphics Design group for sponsoring this work. Thanks to all the people at RIT who provided support and direction, particularly the faculty of the Packaging Science Department and the research librarians. Thanks also to the equipment manufacturers and printers who performed trials and provided samples. Most importantly, thanks to my wife, Peggy, and my daughters, Becky and Erin for their patience and understanding during the times when I was not available to them because I was busy performing this research.

An Assessment of On-Line Package Customization for Sheet Size Products Packaged in Paperboard Envelopes

By

Kevin T. Kennedy

ABSTRACT

This study evaluates the on-line printing of paperboard envelopes as a means of supporting the need to provide customized packaging. Market forces and new business models are contributing to the need for customized packaging and rapid response to orders. Large retailers are demanding unique packaging presentations and global marketing requires localized packaging for different regions of the world. A business environment of just-in-time delivery and minimal inventory levels demand flexibility to react to unpredictable product mix and volumes. These conditions require customized packaging within short cycle times. The traditional carton printing process using offset lithography does not respond quickly enough to meet these needs. Alternate methods of applying graphics to paperboard envelopes provide the capability to respond to the need for customized packaging quickly. This study evaluates several alternative application methods to test the hypothesis that on-line graphics application can provide high quality graphic presentation for low volume, customized packages at a cost that is competitive with traditional offset carton printing.

Contents

List of Tables

List of Figures

I. The Background of the Problem

The Move Toward Customized Packaging

Market demands on companies that manufacture and market products have changed dramatically in recent years. This is particularly true for companies marketing consumer products. Modern technology has provided consumers with access to a larger base of potential suppliers and a correspondingly wide selection of products to choose from.

In the early stages of mass production, manufacturers/marketers could provide a single standard product to meet the needs of the market. Consumers had access to a very limited number of suppliers and most could not afford the substantially higher cost of custom made items. Henry Ford's statement that "You can have any color you want, as long as its black."[1] is indicative of the power wielded by the manufacturer. In most industries, market forces have shifted the balance of power in favor of the consumer. "It used to be that the manufacturer dictated what the consumer could buy. Now it's the consumer calling all the shots."[2]

---

[1] Key Drivers for the Future of Manufacturing, Pp 1.
[2] Jim Shepherd: Advanced Manufacturing Research. Boston Business Journal, October 13, 1995

As more competitors enter the market and technology enables consumers to deal with a larger base of suppliers, manufacturing/marketing companies are forced to meet the unique needs of different types of consumers. "The number of competitors in an industry, how strongly they compete and the extent to which they battle for market share can have a great impact on where the industry stands on the spectrum between mass production and mass customization."[3]

The chart below illustrates the evolution of manufacturing over the past 100 years.[4]

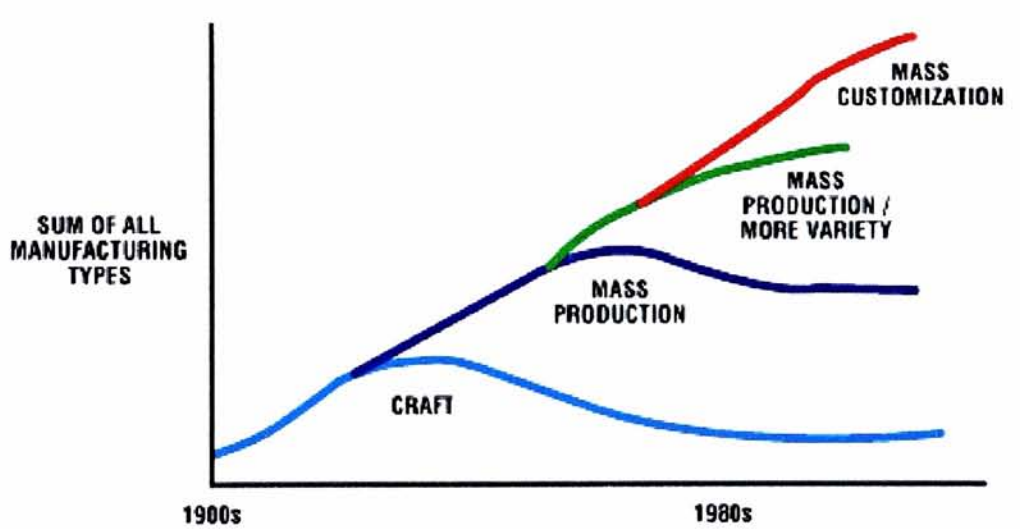


Figure 1 - The Evolution of Manufacturing

...It is not happenstance that the globalization of markets ... has coincided with increased turbulence and the breakdown of the system of mass production."[5]

---

[3] Pine. Pp. 63
[4] Key Drivers for the Future of Manufacturing, Pp 2.
[5] Pine. Pp. 63

As a result of changes in the marketplace, technological innovation and new business models, manufacturers and marketers are being forced to provide products customized to meet the unique requirements of different market segments and niches within each segment. Markets are being increasingly fragmented as customers demand products that meet their specific needs, not the generalized needs of demographically similar customers. "By the time the market has been segmented and niches have been carved out, the number of differentiated parts is considerable. "[6]

There are different types of customization which can be employed in different circumstances:[7]

- **Collaborative Customization** – working with the customer to identify needs and then make a product customized to the particular needs of that buyer.
- **Adaptive customization** – One standard, but customizable, product is designed so that users can alter it themselves to suit their particular needs.
- **Cosmetic Customization** – Presentation of a standard product differently to different customers.
- **Transparent Customization** – provide different products to different customers in a standard presentation.

One of the options for meeting the need for customized product offerings is to present a standard product in a variety of different packaging formats designed to appeal to the particular needs and want s of each market (cosmetic customization).

---

[6] Davis, Pp. 168-169.

For companies competing globally and those marketing through retail channels several factors are significant in driving the use of customized packaging.

Mass Merchandisers – Mass merchandise discount stores, category superstores and warehouse club stores have tremendous power in the market. The table below shows the number of outlets and sales volumes for some of the larger chains that distribute paper products (combined sales volume in excess of $200 billion):

Company	*Number of retail Outlets*	*Annual Sales*
Wal-mart[8]	2400 +	$100 Billion
K-Mart[9]	2100 +	$34 Billion
Target Stores[10]	900 +	$23 Billion
Walgreens[11]	2800 +	$18 Billion
Best Buy[12]	300	$10 Billion
Office Depot[13]	400	$9 Billion
CompUSA[14]	200	$6.3 Billion
Staples[15]	300	$5 Billion

Table 1 – Mass Merchandisers for Paper Products

---

[7] Gilmore and Pine
[8] www.wal-mart.com
[9] www.kmart.com
[10] www.targetstores.com
[11] www.walgreens.com
[12] www.bestbuy.com
[13] www.officedepot.com
[14] www.compusa.com
[15] www.staples.com

"The greater the power of the buyers in an industry, the less companies can control their environment. ...Companies have to respond more to what their customers need and want. This results in more variety and customization as firms differentiate their products."[16] Because of the large number of customers they have access to and the quantities they purchase to stock their stores, these companies can and do negotiate concessions from their suppliers. One of the conditions for getting onto the shelf in these outlets is often to provide a product unique to that particular channel and not available to the consumer anywhere else. This condition is frequently met by providing standardized product in a unique package configuration. "Cosmetic customizers present a standard product differently to different customers. The cosmetic approach is appropriate when the customers use the product in the same way and differ only in how they want it presented. The standard offering is packaged specifically for each customer."[17] The impact of this move toward customized packaging for different retail channels is very significant to the supply chain. Customization for different retail channels can significantly increase the number of SKUs produced, as illustrated below.

[16] Pine. Pp. 61
[17] Gilmore and Pine. Pp. 93

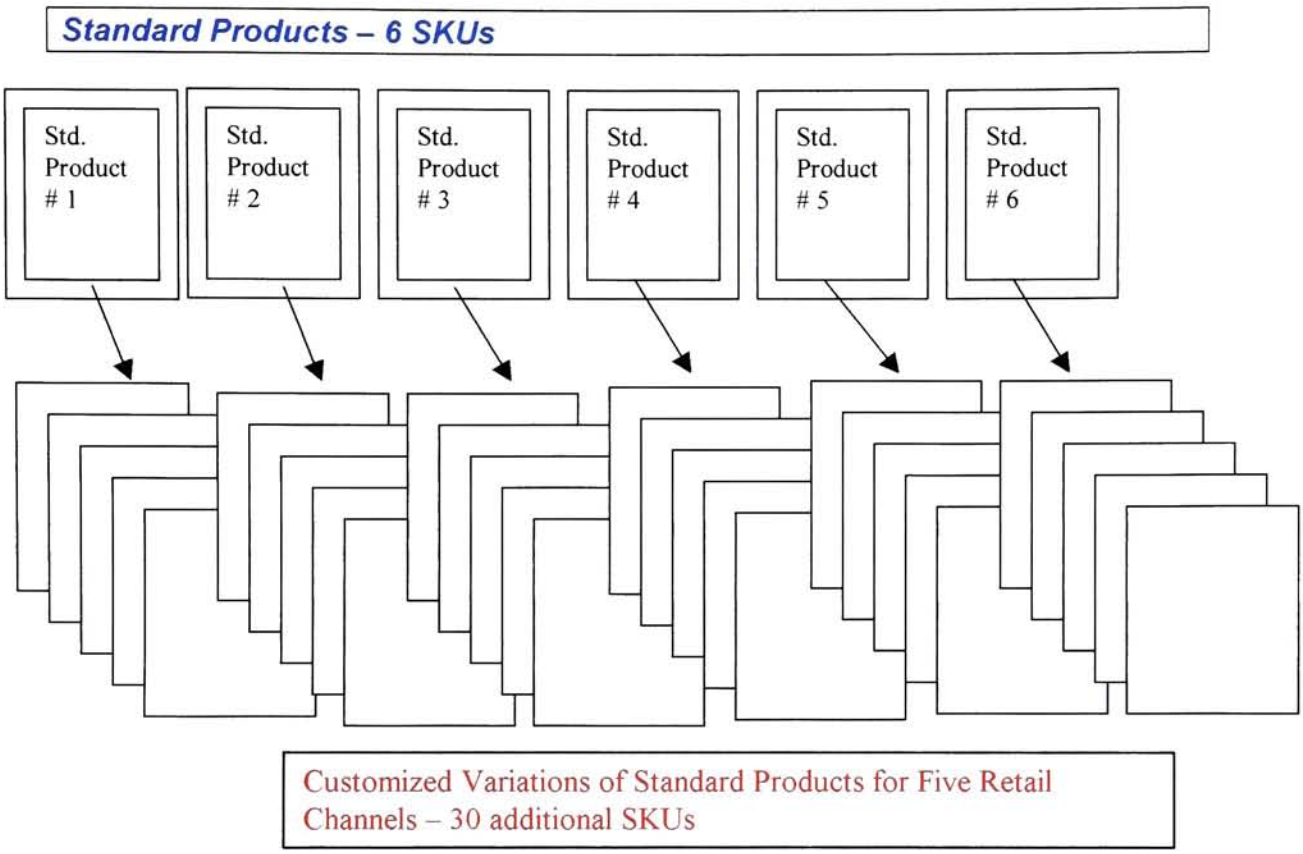


Figure 2 - SKU Proliferation

Localized Packaging – Another force leading to increased package customization is the need to provide packaging that meets specific needs or preferences of different countries or regions. An obvious example of this would be packaging with text in the local language. For example, 3M Company has been challenged by the need to provide label information in local languages. "Customers prefer to have label information printed in English as well as a local language, especially in emerging markets. The presence of local language can provide a competitive advantage. If

consumers can read the package copy in their local language, they'll respond positively."[18] There are many other examples of localized packaging including cultural preferences for different colors, unique environmental restrictions and differences in the way products are displayed in different markets.

Integrated Supply Chain

Packaging a standard product in a variety of formats has significant cost implications with respect to finished goods inventories. Under the mass production model, product are manufactured, packaged and placed in inventory to fulfill anticipated future orders. Items are planned and produced based on projections of future sales based on historical patterns. Since the actual orders are unknown, it is necessary to inventory each of the various configurations of the product in sufficient quantity to meet expected orders plus safety stock to account for the uncertainty around the projected volumes. "The hallmark of customization is uncertainty. You don't know what you are going to ship until you get an order. Because customized production is so dynamic, …real time data about inventory, production and the ability to respond immediately to problems becomes a necessity." – Art Brown, Director of Supply Chain Markets, Synquest.[19]

As the number of formats required to meet customer needs proliferates, the amount of material in inventory increases proportionately. Despite these

---

[18] Reynolds. Pp 2.

high inventory levels, it is possible to stock out of one format due to an unexpectedly large order while having excess inventory on another format that didn't sell as well as expected. For example, a manager of a health and beauty products ware house states "With the proliferation of packaging requirements from major retailers, our number of SKUs has exploded. We have situations daily where we backorder one retailer, like Wal-mart, on an item that is identical to an in-stock item except for the packaging."[20] In order to support the need for customized packaging, a different business model is required.

An integrated supply chain is one in which common information is shared across functions within the organization. The sharing of information leads to significantly reduced time between the planning of an order and the shipment of the order to a customer. One objective of an integrated supply chain is to minimize the amount of resources tied up in work-in-process. Ideally, resources would not be committed until a customer order is in hand. In order to move toward this ideal state, information flow must be almost instantaneous and the manufacturing process flexible enough to respond to the irregular demand. Recent technological developments in information systems, manufacturing processes and logistics have created the potential to move significantly closer to this ideal.

---

[19] Gooley. Pp. 3.
[20] Anderson, et al, Pp. 5.

Packaging Postponement

In order to achieve the level of flexibility needed to fulfill orders on a just-in-time basis it is desirable to delay the differentiation of the product until the latest point possible within the manufacturing process. In the case of customized packaging of a standard product, this means postponement of packaging until the format needed to fill the order is known.

"Postponement of assembly offers some of mass customization's most important benefits: lower overhead and inventory, shorter production development cycles, reduced stock obsolescence, postponed cost until ready to bill, and the ability to respond quickly to changing customer needs."[21]

Figure 3 shows an example of packaging postponement for a standard bracket. This concept applies to a wide range of products including standard sheet products.

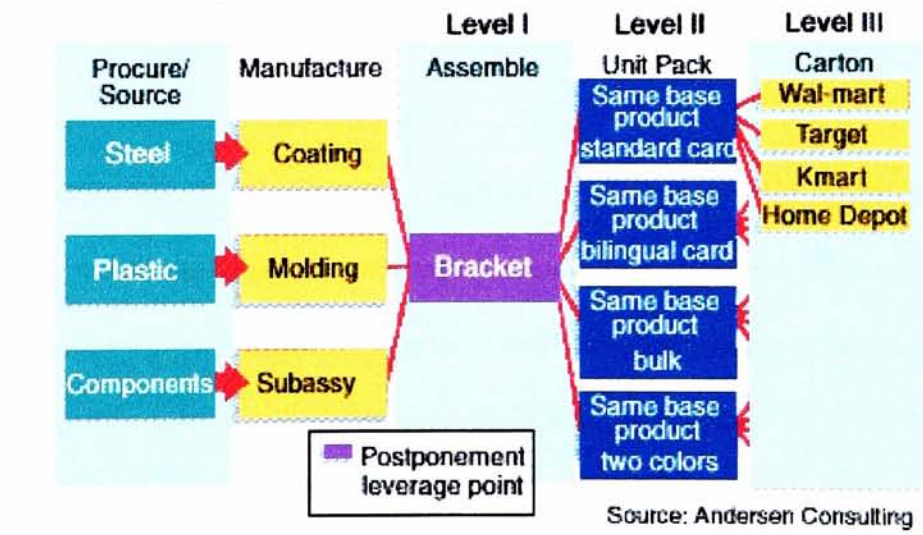


Figure 3 - Packaging Postponement

[21] Gooley. Pp. 3.

Dell Computer (Round Rock, Texas) is widely recognized as a leader in the field of mass customization and postponement. Unlike other manufacturers, Dell does not assemble its computers until a customer has placed an order. Dell keeps a minimum of inventory on hand. Customizing and postponement allow Dell to deliver new technology to its customers more quickly than its competitors because they can quickly reconfigure their computers and have little inventory in front of them. "Because it produces only what customers order, Dell never has to unload warehouses full of outdated computers."[22]

In-Line Package Customization

Many possible options exist for the implementation of customized packaging. These options span a range of technology from traditional off-line printing to digital on-line printing. Some of the significant options are discussed below.

Offset Lithographic Printing

Traditional offset lithography is the most widely used printing process for paperboard folding cartons. In this process, there are several off-line steps that take place before the job goes to press. Several of these steps, color separation, plate making and make ready have a significant impact on both cost and lead times for printing. First, color separations are made by outputting each of the different color (CMYK) line screens to film,

[22] Toberson. Pp. 6.

typically using a laser image-setter. This requires time the consumption of the material (imagesetting films) and time to image the films and then process them.

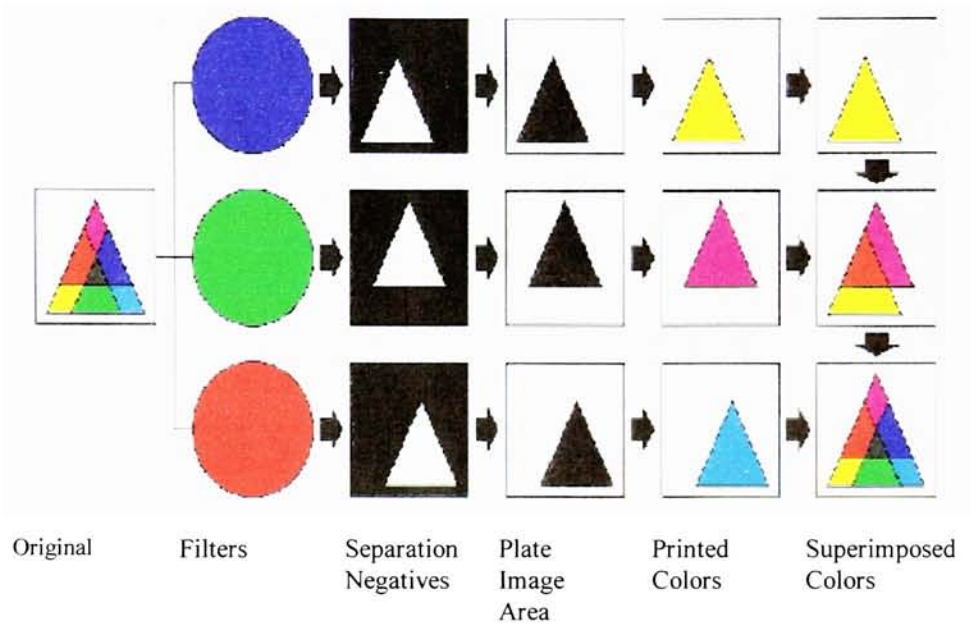


Figure 4 - Color Separation Process[23]

These films are used to produce the printing plates that transfer the ink to the print blanket. This process also requires the consumption of materials, typically aluminum plates, and time to image from the color separation films and to process the plates.

[23] RIT Orientation to the Graphic Arts - 1996

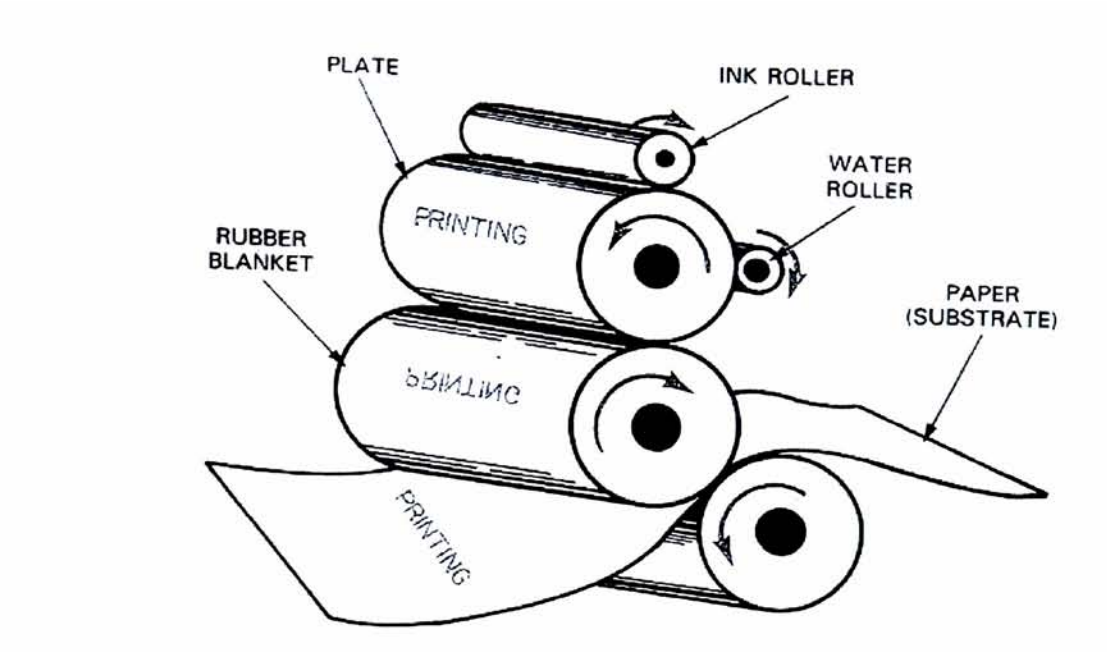


Figure 5 - Offset Lithography[24]

Finally in make ready, the printing plates are physically mounted on cylinders on the press and aligned for proper print registration. During this process, the press is not running. This downtime can be very expensive on a multi-million dollar printing press and efforts are made to keep it to a minimum.

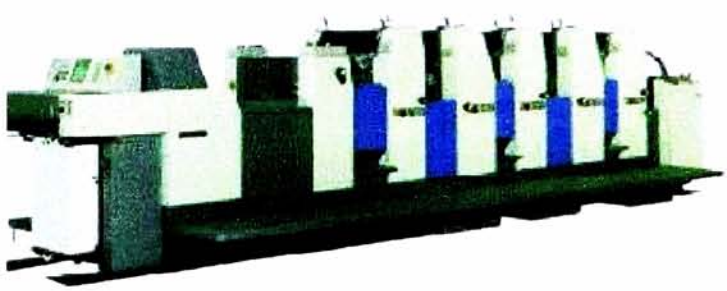


Figure 6 - Five Color Offset Press[25]

---

[24] RIT Orientation to the Graphic Arts - 1996
[25] Ryobi North America Inc.

The costs associated with pre-press and make ready must be spread over the number of printed pieces produced. These combined costs typically run several thousand dollars. When spread over a large number of impressions, these costs become insignificant. For small runs of several thousand impressions these costs can be prohibitive.

Digital Printing Presses

A number of companies now market digital printing presses. Various technologies are used to produce the image on the substrate. All of the presses have a digital front end or pre-press process. Artwork and copy are converted to a digital file, color separations are produced digitally and the image is created on press. Some systems make plates on press and others create the image directly onto the print drum using electronic charges. (See figure 7 below.)

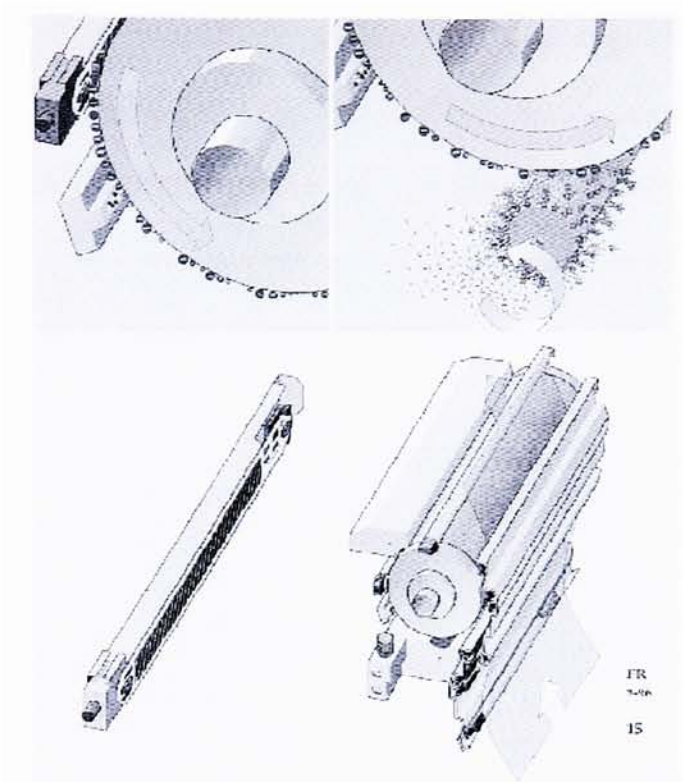


Figure 7 - Digital Printing Process[26]

The inks or toners used have an opposite charge to those areas on the drum to be imaged. This eliminates the need for color separations on film, and the creation of print plates used in traditional offset processes. Since there is no need for mounting printing plates at each print station, make ready and changeover time on the presses is minimal. In some cases, each impression can be changed without stopping the press. These advantages make these presses especially well suited to short run work including customized packaging. (See Appendix A for diagrams and specifications for the systems discussed below.)

[26] Xeikon America Inc.

Any of these systems can be integrated with coating or laminating stations and die cutting stations in-line. Ideally, the finishing equipment would have as much flexibility as the digital press. Recently developed digital laser cutting equipment has the capability to cut and score cartons directly from a Cadd file without tooling such as rule dies (See Appendix E).

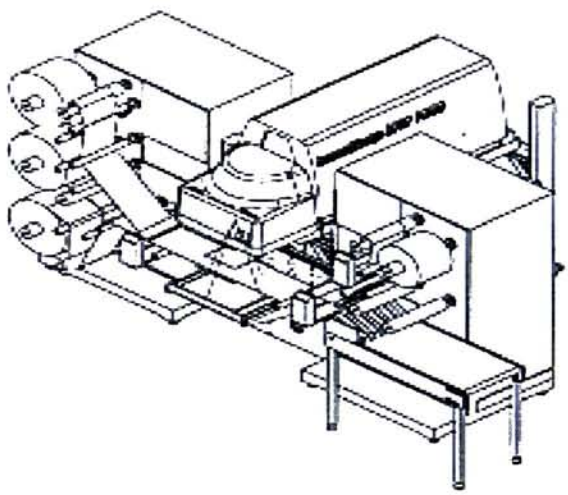


Figure 8 - Digital Laser Cutting Equipment[27]

Heidelberg

Heidelberg's solution to short run printing is to apply digital pre-press processes on a press that prints with a waterless offset lithography process. This option takes advantage of developments in digital pre-press to reduce the set-up time involved in plate making and make ready in traditional offset lithography. The Heidelberg process uses laser diodes to image print plates on press. At the same time, Heidelberg takes advantage of the

quality and low per impression costs associated with offset printing processes. Because this process is still an offset printing press, a skilled pressman is needed to run this type of equipment. It is necessary to clean up the imaging rollers between runs and it takes several minutes to electronically generate print plates for the next run.

Figure 9 - Heidelberg Digital Press[28]

The basic unit currently available is the Quickmaster DI-46. The base press has 4 print stations. An upgraded model with 6-color capability is also available. This press has a footprint of approximately 8 ft. x 8 ft. It is a sheet fed press capable of handling a maximum sheet size of 18 inches x 13 inches on stocks between 0.0024" and 0.012" thick. The press is capable of producing 7000 A4 size impressions per hour.

---

[27] LasX IndustriesInc.
[28] Heidelberg USA Inc.

Indigo

Indigo also uses digital pre-press and offset liquid ink printing, but the press itself is not a traditional multiple print station press like the Heidelberg presses. Instead, the Indigo system uses completely digital pre press with no print plates and a single print station which prints the different colors (up to six) in turn by cleaning and re-imaging the print system for each color. The press is capable of producing 2000 A4 size images per hour in four colors.

Figure 10 - Indigo Digital Press[29]

The only unit currently available with the capability of printing on paperboard for cartons is the Omnius. This unit can handle sheet sizes up to 13" x 18", producing a maximum image size of approximately 12" x 17". The process can handle stocks between 0.0024" and 0.012" thick.

[29] Indigo USA Inc.

Xeikon

Xeikon employs a similar digital direct to press pre-press process to that used by Indigo. Xeikon is unique in its use of dry toner electrophotography to produce the printed image. This press has four printing stations, one for each of the process colors (CMYK).

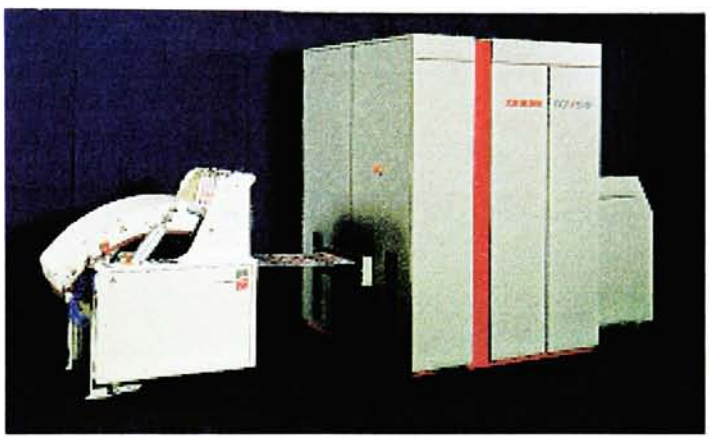


Figure 11 - Xeikon Digital Press[30]

The Xeikon DCP/50 SP is specifically designed for printing paperboard packaging and can handle substrates up to 0.016" thick. Another unique feature of the Xeikon presses is that it re-images the image roller for each impression. The image is continuously erased and replaced by a new image as the roller turns. As a result, there is no fixed repeat on the length of the impression and it is capable of producing a continuous image up to 26 feet long. The 50cm press can handle stock up to 20 inches wide, with a maximum image width of 18.8 inches. The Xeikon unit can produce 3000 A4 size images per hour.

[30] Xeikon America Inc.

Intelligent Thermal Transfer Printing (Thermal Transfer Coding)

As the name implies, thermal transfer printers use heat to transfer pigmented material from print ribbon to the surface to be printed. Print ribbons can use wax, resins or wax/resin combinations as the pigmented material. Using different types of ribbons makes it possible to print on a wide range of substrates. Print resolution can range from 200 to 600 dpi with 300 dpi systems being the most common. There are a number of companies making thermal transfer printing systems. Weber Marking System's Easyprint and Markem Corporation's Smartdate are representative of these systems (See Appendix D for specifications)

Figure 12 - Thermal Transfer Printer[31]

These systems can be continuous motion for web substrates or intermittent motion for packages such as folding cartons. These systems can be used to apply spot printing of a small area in a single color. For customization, pre-printed cartons or envelopes would be produced in volume on an offset press with product family graphics. Certain areas of the carton would be

reserved for the imprinting of variable information such as sheet count and bar coding with thermal print stations. Because the amount of information to be printed in this process is limited, the ability to customize is limited to the information in those fields.

Pre-Printed Cover Sheets

Pre-printed cover sheets are typically produced using offset lithography as discussed above. For customization, cover sheets would carry all of the variable information including product specific graphics, instructions, etc… The cover sheet(s) would then be inserted into a standard envelope using sheet counting or collating equipment (See Appendix F for an example of a typical sheet counting system).

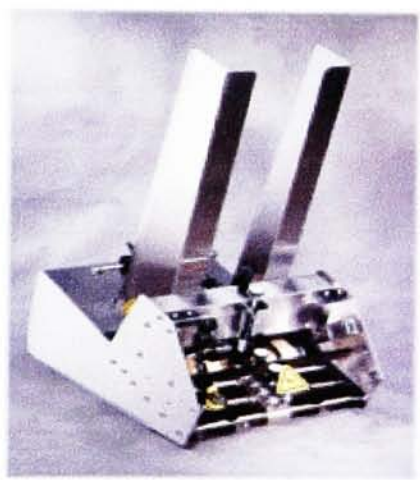


Figure 13 - Friction Sheet Feeder[32]

[31] Markem Corporation
[32] Streamfeeder LLC

The envelope would be pre-printed with generic branding graphics and the cover sheet(s) would convey the variable information. The cover sheet would be visible through windows in the envelope.

Because offset printing is used to produce the cover sheet(s), the same cost and lead-time issues that apply to printing the envelope also apply to cover sheets. There are however several potential benefits to the cover sheet concept. Because they are smaller and less complicated to produce, customized cover sheets cost less than a comparable printed envelope at the same volume. They are easier to store – one shipping case could hold 5,000 sheets – requiring less cost and space for inventory of supplies. Using cover sheets would make it possible to get the most economical pricing on envelopes because large runs would be made with standard graphics. Finally, the use of cover sheets could provide greater flexibility in filling customer orders by facilitating postponement. Standard products could be produced in generic cartons and cover sheets inserted to customize as orders are received.

The Significance of the study

Market forces are driving manufacturers and marketers toward increased customization of their products and packages. Many major retailers are demanding customized presentation of standard products to differentiate their offering from those of their competitors. In addition, global marketing requires different packaging that meets the needs of local markets. These trends are dramatically increasing both the number of SKUs offered and related packaging formats. Fragmentation of the product line results in smaller print runs, the need to inventory an ever increasing number of packages, frequent set-up changes on the packaging line and increased finished goods inventory. In this environment, the ability to postpone packaging and product differentiation presents the opportunity to reduce inventory of packaging supplies, gain cost efficiencies in off-line printing operations, increase flexibility to meet customer needs and reduce the need for finished goods inventory. The ability to provide customization of the package in a cost-effective way is essential to this strategy. This study will evaluate four (4) different approaches to package customization, comparing fully customized pre-printed envelopes to three different on-line customization options.

The envelope/carton that is the focus of this study has some unique requirements which will influence the choice of customization options.

Carton blank size - 16" x 22"
Print Graphics - High graphics content including photo images
Design Elements – Unique images for each product
Carton Stock - 14 point SBS

II. The Problem and its Settings

The Statement of the Problem

This study proposes to evaluate the relative value of the application of selected packaging customization concepts to a product line of letter size sheet products packaged in paperboard envelopes. This will require discussion of packaging postponement, package customization methods and an evaluation of different options available for customization of the envelopes. Options will be evaluated on the basis of economics, quality of graphics presentation, compatibility with existing manufacturing processes and technical risk.

The Hypothesis

This study will test the hypothesis that on-line printing/graphics application for low volume, customized packages facilitates packaging postponement by providing high quality graphic presentation with shorter lead times at a total cost competitive with traditional off-line envelope printing.

The Delimitations

1. This study will focus primarily on costs associated directly with the primary packaging (the envelope and graphics) for the product. Although postponement and on-line package differentiation facilitate significant opportunities for cost reduction in areas such as reduced finished goods inventory, detailed analysis of these costs is beyond the scope of this study.
2. This study will evaluate a sampling of printing technologies representing a range of on-line customization capabilities. The range of possible approaches to on-line

customization is almost limitless and this study will not attempt to be all encompassing.

The Definition of Terms

Mass Customization – Mass manufacture of products made to unique requirements of different customers

Channel Partner – A major distribution channel, such as a major retail chain (e.g.; Wal-mart), with whom the marketer works cooperatively.

Postponement – To delay the differentiation of the product for a specific customer or distribution channel until the latest possible point in the supply chain.

In-line Package Customization – Processes that allow for application of customized packaging graphics and variable text during package assembly (as opposed to traditional off-line print runs).

Abbreviations

SBS – Solid Bleached Sulfite

SKU – Stock Keeping Unit

Assumptions

1. Paperboard stock will be 14 point SBS for all envelopes regardless of customization option.

2. Monthly volumes for each SKU are constant at 1/12 of annual volume

3. Each carton is re-ordered on a monthly basis and monthly delivery quantity is 1/12 annual volume.

4. Packaging labor costs associated with envelope loading, shrink wrapping and casing will be the same for all options

Customized packaging options to be evaluated include:

Option #1*(Current Process)* – Fully customized pre-printed cartons (traditional offset lithography) for each SKU. (See Figure 8.)

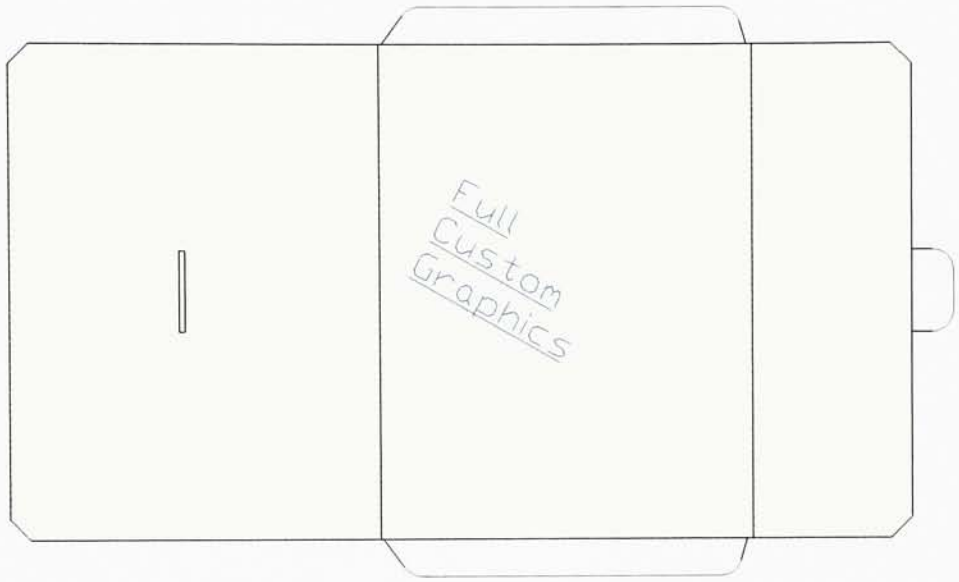


Figure 14 - Pre Printed Offset Custom Carton

Option #2 – Pre Printed customized carton for each standard product with drop out (unprinted and uncoated) areas for variable information such as sheet count, stock number and bar codes to be printed in-line with Intelligent Thermal Transfer Coder technology. (See Figure 9)

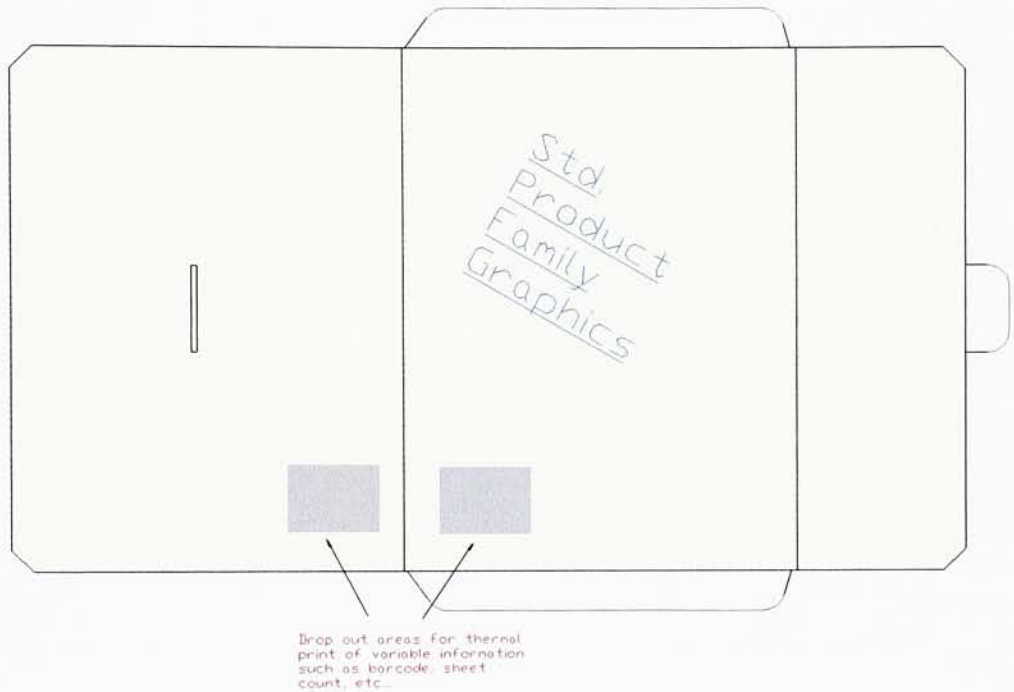


Figure 15 - Standard Pre Printed Carton for Thermal Printing

Option #3 – Preprinted standard windowed envelope with basic branding information and cross sell information pre-printed. Customized graphics and variable information pre printed on cover sheets, which are inserted into the standard envelope in-line during packaging operation. (Figure 10)

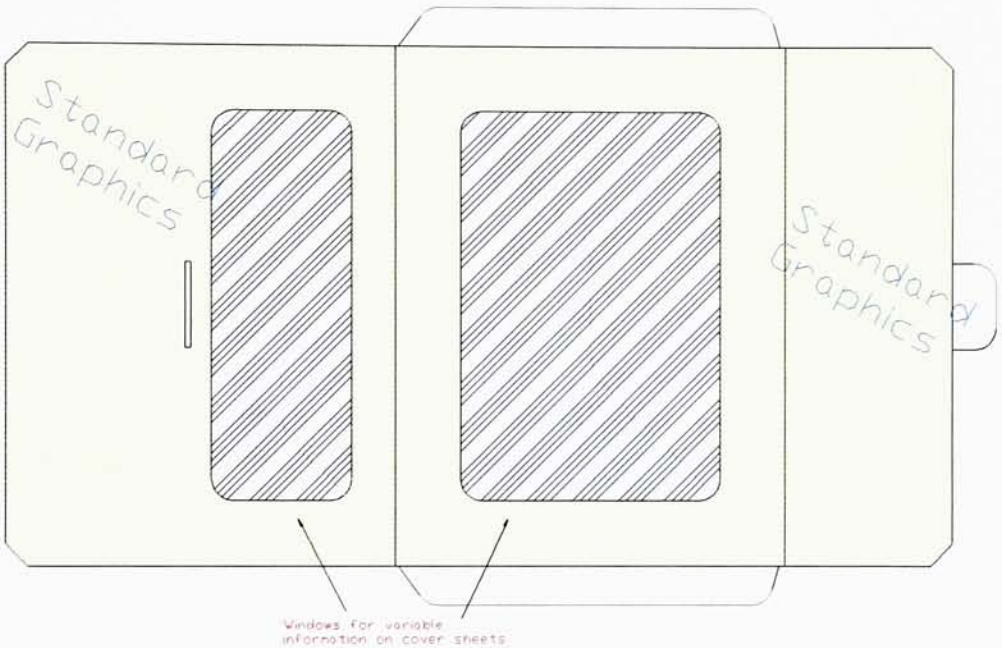


Figure 16 - Standard Windowed Carton for Cover Sheets

Option #4 – Fully customized in-line digitally printed cartons. (See figure 11)

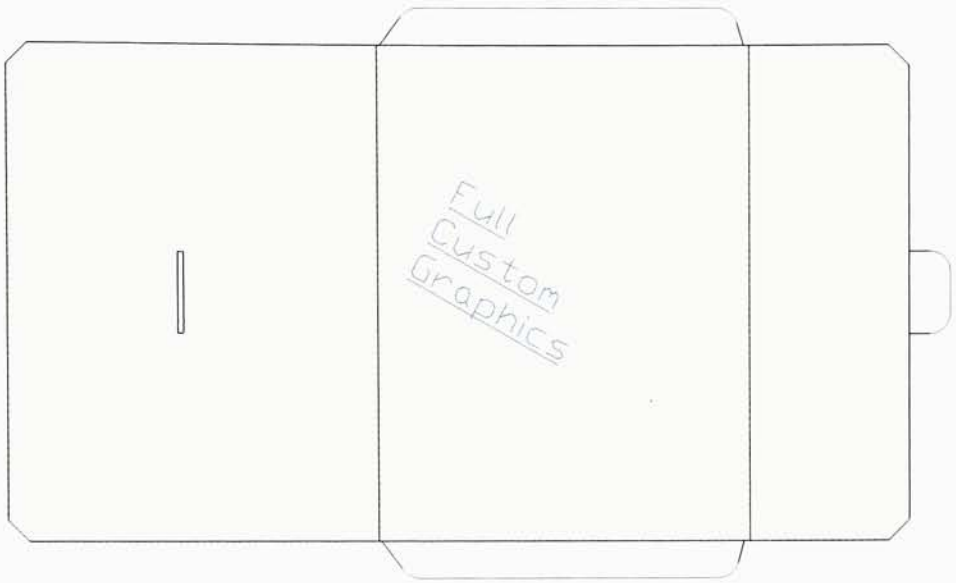


Figure 17 - Digitally Printed Custom Carton

III. The Data and the Treatment of the Data

The Research Methodology

This research will be conducted as a case study of the application of different customization options for printed paperboard envelopes. The options will be evaluated individually and compared to one another. Information on cost components will be collected for each option and total package cost compared. In addition to cost, the options will be compared to one another for quality of graphic presentation, compatibility with existing manufacturing operations, flexibility and technical risks associated with implementation.

The Treatment of the Data

Cost – cost data will be compared in tabular and graphical formats that compare relative costs for each option across a range of delivery volumes. Comparisons will be made for significant cost components, such as material and capital, and projected total cost.

Print Quality – quality of graphic presentation will be assessed subjectively for color reproduction, image quality and overall appearance. Assessments for in-line customization options will be assessed using the current offset printing process as a benchmark

Process Compatibility – compatibility with existing packaging processes will be assessed for each option and potential issues will be documented. The options will be assigned a relative ranking for compatibility. Comparative results will be presented in tabular form.

Flexibility – Flexibility will be assessed based on the degree of customization possible using each option as well as the time needed to execute a modified or new graphic treatment. Results will be presented in tabular form.

Technical Risks – Risks will be documented for each option and assigned a risk factor of high, medium or low. Comparative results will be presented in tabular form.

Overall – Comparative results for all options will be presented in tabular form with a relative ranking in each category plus an overall rating.

The Data

Description	Annual Volume - Packages	Monthly Volume
Product #1	1185000	98750
Product #2	407500	33958
Product #3	121500	10125
Product #4	216000	18000
Product #5	133500	11125
Product #6	43000	3583
Product #7	56500	4708
Product #8	40500	3375
Product #9	56000	4667
Product #10	22500	1875
Product #11	22500	1875
Product #12	36000	3000
Product #13	47500	3958
Product #14	26500	2208
Product #15	29000	2417
Product #16	5500	458
Product #17	30000	2500
Product #18	60000	5000
Product #19	470500	39208
Product #20	91000	7583
Product #21	37000	3083
Product #22	35000	2917
Product #23	36000	3000
Product #24	33000	2750
Product #25	26500	2208
Product #26	15000	1250
Product #27	10500	875
Product #28	91000	7583
Product #29	56500	4708
Product #30	86500	7208
Product #31	21000	1750
Product #32	5500	458
Product #33	21000	1750
Product #34	210500	17542
Product #35	147500	12292
Total for All Products	**3933000**	**327750**

Table 2 - Sales Volume data for individual SKUs and Monthly Delivery Volumes for Each

Cost data:

Delivery Volume	*Cost per 1000 cartons*
1,500	**$1,150**
3,000	**$705**
6,000	**$427**
12,000	**$313**
18,000	**$273**
25,000	**$238**
30,000	**$217**
36,000	**$204**
42,000	**$193**
48,000	**$186**
54,000	**$181**
60,000	**$176**
90,000	**$162**
120,000	**$155**
240,000	**$138**

Table 3 - Fully Customized Pre-printed Carton Costs

at various delivery volumes
14 pt. SBS
2.4 Sq. Ft. per impression
6 color printing

The above prices also apply to pre printed cartons for on-line customization:

Pre-printed standard cartons for on-line thermal transfer coding customization

Pre-printed standard windowed cartons for cover sheet insertion

Delivery Volume	*Cost per 1000 Sheets*
1,000	**$866**
2,500	**$509**
5,000	**$318**
10,000	**$199**
25,000	**$100**
40,000	**$76**
50,000	**$66**
75,000	**$61**
100,000	**$49**
200,000	**$39**

Table 4 - Pre-printed Cover Sheet Costs

at various delivery volumes
80# Coated Stock
9"x12". per impression
6 color printing

Delivery Volume	*Cost per Carton (2 cover sheets – Front/Back)*	*Generic Carton Cost (Bulk Price)*	*Total Customized Carton Cost per Unit*
1,000	**$2.26**	**$0.14**	**$1.88**
2,500	**$1.26**	**$0.14**	**$1.16**
5,000	**$0.64**	**$0.14**	**$0.78**
10,000	**$0.40**	**$0.14**	**$0.54**
25,000	**$0.20**	**$0.14**	**$0.34**
40,000	**$0.15**	**$0.14**	**$0.29**
50,000	**$0.13**	**$0.14**	**$0.27**
75,000	**$0.12**	**$0.14**	**$0.26**
100,000	**$0.10**	**$0.14**	**$0.24**
200,000	**$0.08**	**$0.14**	**$0.22**

Table 5 - Total Customized Carton Costs for Standard Windowed Carton / Pre-printed Cover Sheets

Technical data/specifications for digital printing presses

	Heidelberg DI46	*Indigo Omnius*	*Xeikon DCP/50*
Maximum Image Size	*13"(W)x 17-3/4"(L)*	*12.1"(W) x 17.2"(L)*	*20"(W)x 26'(L)*
Substrate Caliper Range	*0.0024" to 0.012"*	*0.0004" to 0.012"*	*.005" to .016"*
Set-up/Change-over time	*4 to 12 minutes*	*Near Zero can change jobs without stopping*	*Near Zero can change jobs without stopping*
Maximum Speed	*3,500 (A3) Impressions per hour*	*1,000 (A3) Impressions per hour*	*1,500 (A3) Impressions per hour*
Print Process	*Waterless Offset*	*Digital – wet inks (proprietary)*	*Digital – Dry toner electrophotography*
Print Resolution	*1270 dpi*	*800 dpi*	*600dpi*
Colors	*4 color (CMYK) process*	*4 color (CMYK) process*	*4 color (CMYK) process*
Spot Color Option	*No*	*Yes*	*No*
Pre-press Technology	*Digital on-press plate making*	*Digital – direct to press*	*Digital – direct to press*
Ability to customize each impression?	*No*	*Yes*	*Yes*

Table 6 - Comparative Technical Information for Digital Printing Presses

Note: Based on image size and substrate requirements, The Xeikon is the only press suitable for this application. The analysis of the digital print option will be based on the Xeikon press.

Capital Costs

	Pre-printed Offset Litho Carton	*Standard Carton with Thermal Print*	*Windowed Carton with Cover Sheets*	*Digital On-line Carton Printing **
Printing Equipment	N/A	Two (2"x 2") Thermal Coding units $30,000	N/A	Digital Printing Press $500,000
Converting Equipment	N/A	N/A	N/A	Laminating Station and Carton cutting Station $300,000
Conveying Equipment	N/A	Intermittent motion Conveyor with 2 stop gates $35,000	N/A	N/A
Sheet Feeding Equipment	N/A	N/A	2 units to add cover sheets at cartoner $20,000	N/A
Total	**$0.00** *All capital for this option is owned by the printer and cost is indirectly paid in the cost of the printed cartons*	**$65,000**	**$20,000**	**$800,000** *As with the offset litho option, these costs could be born by a printing company and charged back as additional costs for the printed carton*

Table 7 - Costs associated with additional capital equipment to implement each option

Consumable Costs

Pre-Printed Offset Carton	*Standard Carton with Thermal Print*	*Windowed Carton with Cover Sheets*	*Digital On-line Carton Printing* **
N/A Consumables costs are included in printing costs.	**$0.004 per carton** Thermal ribbon @ $36/ 3000 linear foot roll, using 2" per impression on each print head ($0.002 x 2). Balance of consumables costs are included in standard printing costs.	**N/A** Consumables costs are included in printing costs.	**$0.44 per carton** Media - $0.08 Usage Parts - $0.12 Toner - $0.24 (Assumes solid background print with 150% coverage)

Table 8 - Consumables costs for each option

Packaging labor costs for each option

Package assembly costs are assumed to be comparable for all options.

Package customization costs are shown in the material costs for each option.

IV. The Results – Comparison of Options

	Pre-printed Offset Cartons	*Thermal Transfer Coder printing*	*Windowed Carton with Cover Sheets*	*Digitally Printed Cartons*
Printing Costs	$0.14 to $1.15 per carton depending on volume	Similar to pre-printed costs	$0.22 to $1.88 per carton depending on volume	$0.61 per carton (regardless of volume)
Capital Costs	Incorporated in printed carton costs	$65,000 per packaging line	$20,000 per packaging line	$800,000 – *Financing is included in carton print cost above*
Consumables Costs	Incorporated in printed carton costs	$0.004 per carton for thermal ribbons	Incorporated in printing costs	$0.44 per carton – *included in carton print cost above*
Pkg. Labor Costs	Neutral	Neutral	Neutral	Neutral
Total Cost	Lowest cost option for volumes above 5000 units	Similar to offset for all volumes	More expensive than Offset for all volumes	Lowest cost option for volumes below 5000 units

Table 9 - Cost Summary Comparison Table

Description	Annual Volume - Packages	Monthly Delivery Volume	Annual Fully Customized Pre-printed Carton Cost	Annual Carton Cost with Thermal Print	Annual Cost Windowed Carton with Cover sheets	Annual Fully Customized In-line Printed	Lowest Cost Option
Product #1	1185000	98750	$208,560	$220,410	$284,400	$722,850	$208,560
Product #2	407500	33958	$88,428	$92,503	$138,550	$248,575	$88,428
Product #3	121500	10125	$44,591	$45,806	$65,610	$74,115	$44,591
Product #4	216000	18000	$58,968	$61,128	$116,640	$131,760	$58,968
Product #5	133500	11125	$41,786	$43,121	$72,090	$81,435	$41,786
Product #6	43000	3583	$30,315	$30,745	$49,880	$26,230	$26,230
Product #7	56500	4708	$39,833	$40,398	$44,070	$34,465	$34,465
Product #8	40500	3375	$28,553	$28,958	$46,980	$24,705	$24,705
Product #9	56000	4667	$31,696	$32,256	$43,680	$34,160	$31,696
Product #10	22500	1875	$25,875	$26,100	$26,100	$13,725	$13,725
Product #11	22500	1875	$25,875	$26,100	$26,100	$13,725	$13,725
Product #12	36000	3000	$25,380	$25,740	$41,760	$21,960	$21,960
Product #13	47500	3958	$33,488	$33,963	$55,100	$28,975	$28,975
Product #14	26500	2208	$30,475	$30,740	$30,740	$16,165	$16,165
Product #15	29000	2417	$33,350	$33,640	$33,640	$17,690	$17,690
Product #16	5500	458	$6,325	$6,380	$10,340	$3,355	$3,355
Product #17	30000	2500	$34,500	$34,800	$34,800	$18,300	$18,300
Product #18	60000	5000	$33,960	$34,560	$46,800	$36,600	$33,960
Product #19	470500	39208	$95,982	$100,687	$136,445	$287,005	$95,982
Product #20	91000	7583	$38,857	$39,767	$70,980	$55,510	$38,857
Product #21	37000	3083	$26,085	$26,455	$42,920	$22,570	$22,570
Product #22	35000	2917	$24,675	$25,025	$40,600	$21,350	$21,350
Product #23	36000	3000	$25,380	$25,740	$41,760	$21,960	$21,960
Product #24	33000	2750	$23,265	$23,595	$38,280	$20,130	$20,130
Product #25	26500	2208	$30,475	$30,740	$49,820	$16,165	$16,165
Product #26	15000	1250	$17,250	$17,400	$28,200	$9,150	$9,150
Product #27	10500	875	$12,075	$12,180	$19,740	$6,405	$6,405
Product #28	91000	7583	$38,857	$39,767	$70,980	$55,510	$38,857
Product #29	56500	4708	$31,979	$32,544	$65,540	$34,465	$31,979
Product #30	86500	7208	$36,936	$37,801	$67,470	$52,765	$36,936
Product #31	21000	1750	$24,150	$24,360	$39,480	$12,810	$12,810
Product #32	5500	458	$6,325	$6,380	$10,340	$3,355	$3,355
Product #33	21000	1750	$23,575	$23,780	$38,540	$12,505	$12,505
Product #34	210500	17542	$57,467	$59,572	$113,670	$128,405	$57,467
Product #35	147500	12292	$46,168	$47,643	$79,650	$89,975	$46,168
Total for All Products	**3933000**	**327750**	**$1,381,455**	**$1,420,780**	**$2,121,695**	**$2,398,825**	**$1,219,927**

Table 10 - Cost Comparison Table for all SKUs

Products #s in red are candidates for in-line customization

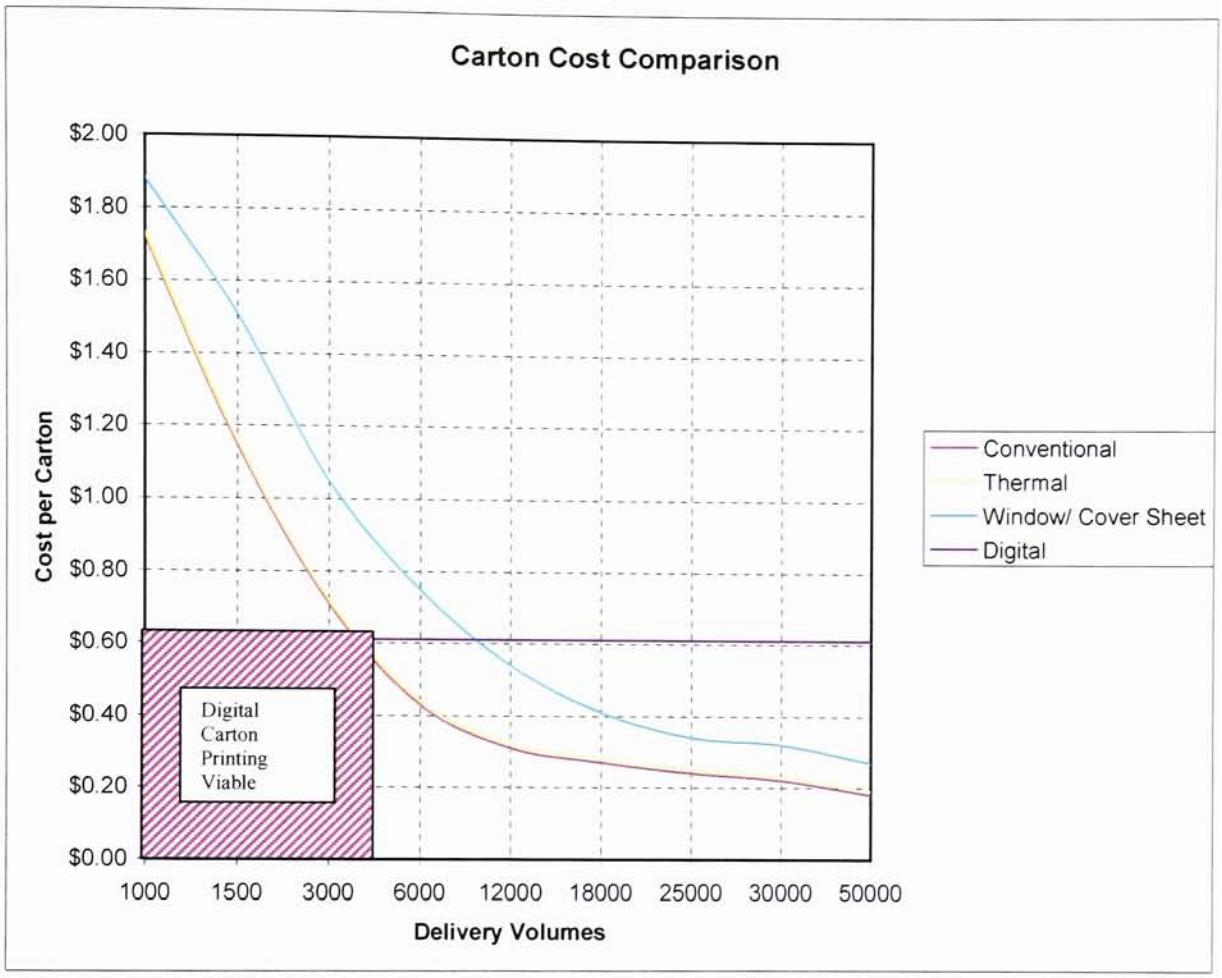


Figure 18 - Comparison of Carton Costs at Different Delivery Volumes

Print Quality Summary Comparison

Pre-printed Offset Cartons	*Thermal Transfer Coder printing*	*Windowed Carton with Cover Sheets*	*Digitally Printed Cartons*
Color reproduction Excellent Quality of text Excellent Quality of photo images Excellent Quality of vignettes Very Good	Color reproduction N/A Quality of text Very Good Quality of photo images N/A Quality of vignettes N/A	Color reproduction Excellent Quality of text Excellent Quality of photo images Excellent Quality of vignettes Very Good	Color reproduction Good Quality of text Very Good Quality of photo images Excellent Quality of vignettes Excellent
Overall Print Quality Excellent See figure 13	**Overall Print Quality** Good –for single color spot text only See figure 14	**Overall Print Quality** Very Good – reduced size may reduce readability See figure 15	**Overall Print Quality** Very Good – four color process limits color rendition See figure 16

Table 11 - Print Quality Comparison

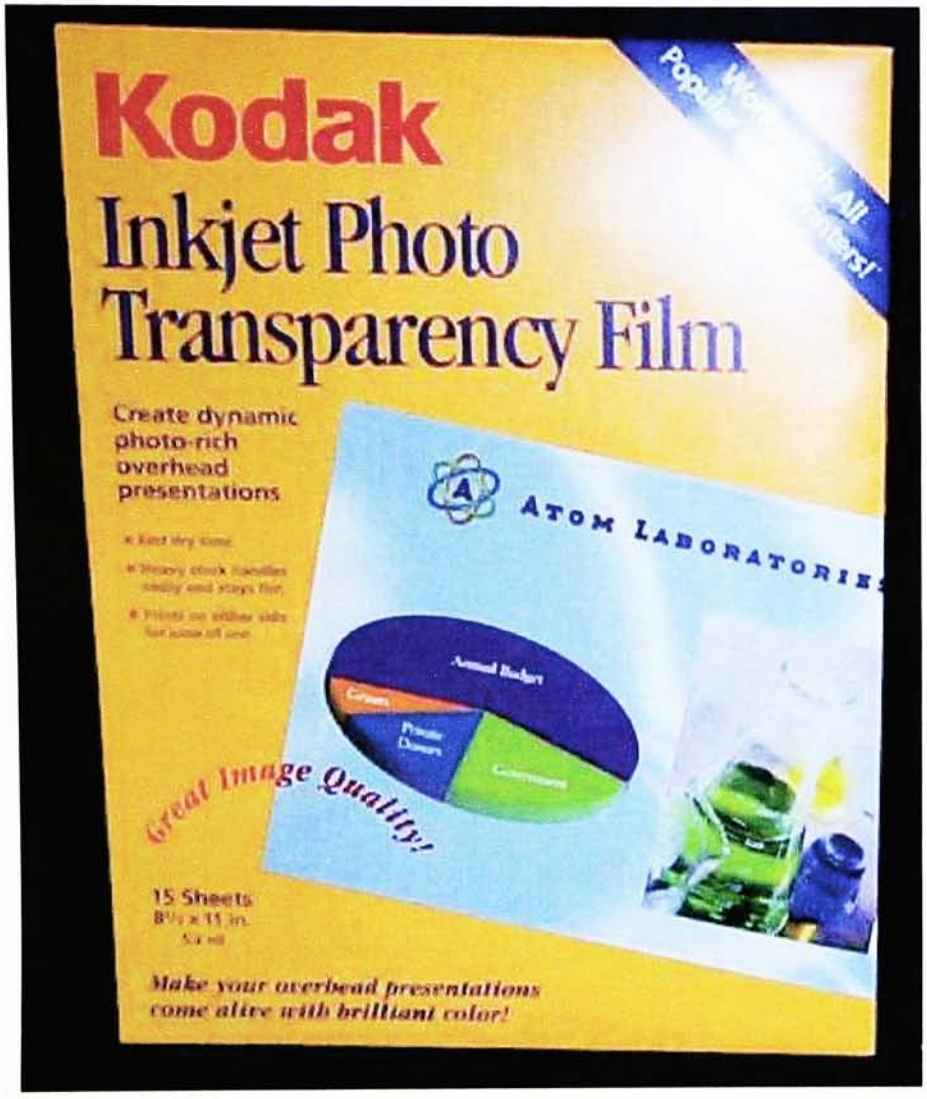
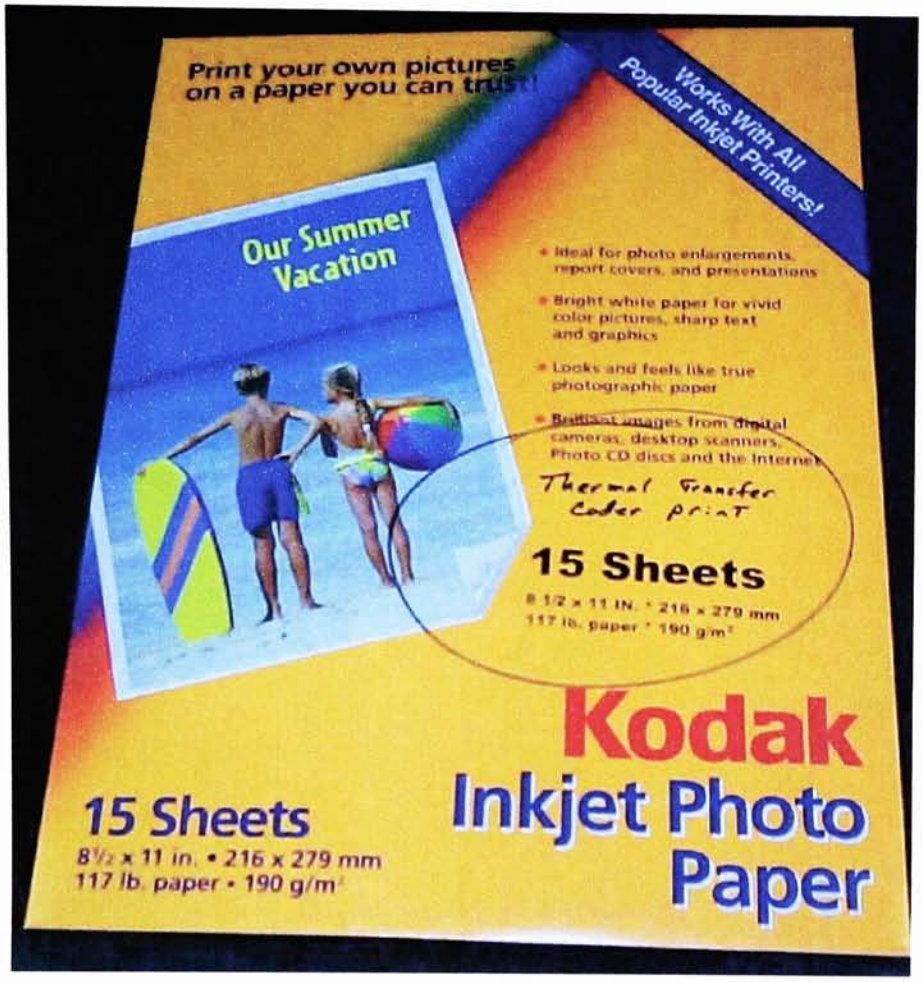


Figure 19 - Fully Customized Offset Printed Carton



Offset Print

Thermal Transfer Coder Print

Figure 20 - Thermal Transfer Coder Printing

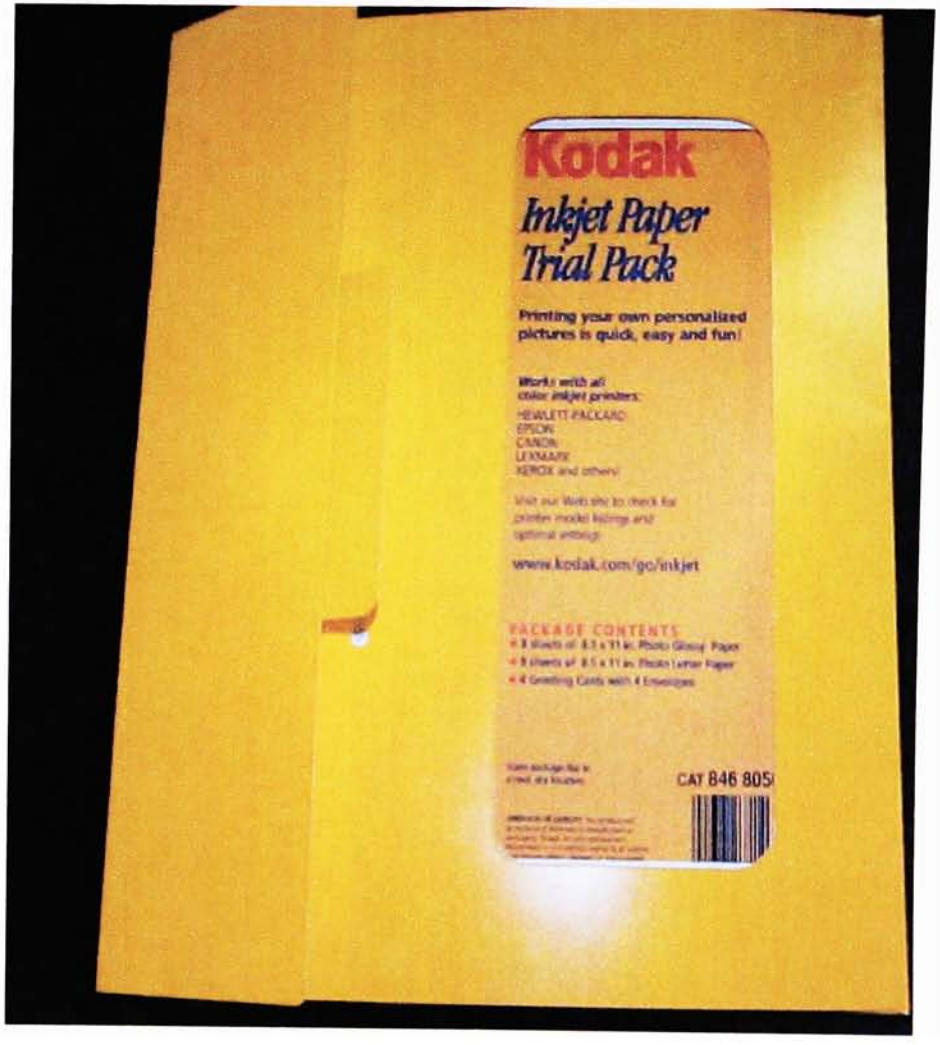


Figure 21 - Windowed Carton with Cover Sheets

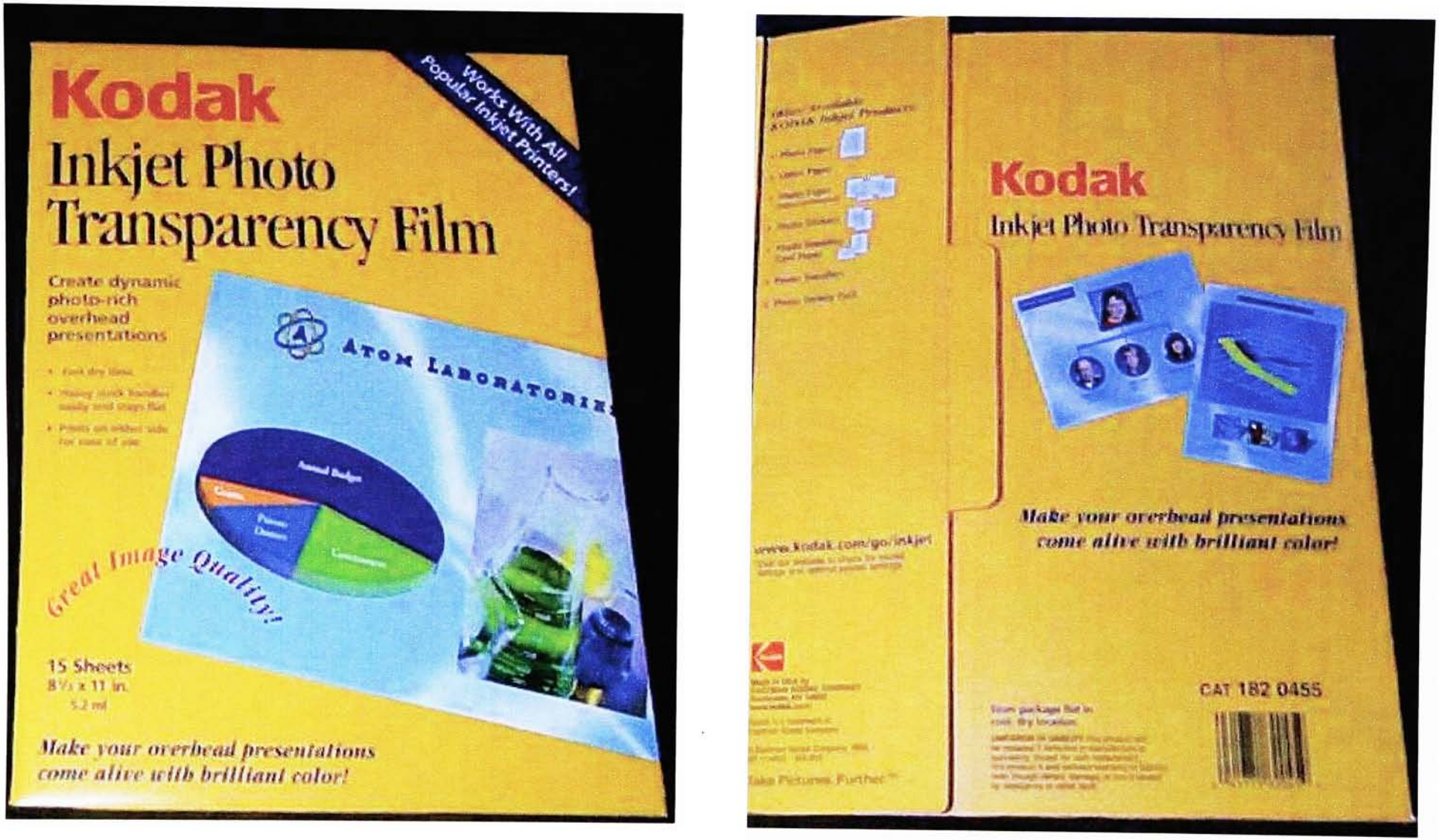


Figure 22 - Fully Customized Digitally Printed Carton

Pre-printed Offset Cartons	*Thermal Transfer Coder printing*	*Windowed Carton with Cover Sheets*	*Digitally Printed Cartons*
High	***Medium/High***	***Medium***	***High***
The current packaging process is designed for the use of pre-printed cartons	This option would require the installation of thermal transfer coding stations (see appendix D) at the front end of the cartoning equipment. Most cartoning equipment can be readily fitted with this type of equipment.	This option would require modification of the staging area of the cartoning equipment to facilitate handling the windowed carton design. It would also require the addition of 2 stations on the cartoner for insertion of the front and back cover sheets (See Appendix F.).	This option is the same as the current process relative to the existing packaging process. The carton printing process would occur off-line, although the cartons might be produced in the packaging area immediately prior to the production run.

Table 12 - Process Compatibility Comparison Table

Pre-printed Offset Cartons	*Thermal Transfer Coder printing*	*Windowed Carton with Cover Sheets*	*Digitally Printed Cartons*
Medium This process allows a wide range of customization options. Standard lead time (after creation of the artwork file) to create color separations, printing plates and schedule a press run is 3 weeks	***Low*** This process provides very limited opportunity for customization on a standard pre-printed carton. Lead time to program the information can be near zero.	***Medium/High*** This process allows a wide range of customization options. Standard lead time (after creation of the artwork file) to create color separations, printing plates and schedule a press run is 3 weeks	***High*** This process allows a wide range of customization options. Lead time to create a new or modified carton is limited to the time needed to create the graphics artwork file.

Table 13 - Flexibility Comparison Table

Pre-printed Offset Cartons	*Thermal Transfer Coder printing*	*Windowed Carton with Cover Sheets*	*Digitally Printed Cartons*
Minimal	***Low***	***Moderate***	***Moderate***
This is the current process. The technology is well developed and understood	This technology is widely used for packaging applications. The application of thermal printing to a pre-printed, die cut carton blank does present some technical challenges. The irregular shape of the carton blank makes proper positioning of the blank for printing more difficult.	The technology for producing the cartons and cover sheets is readily available and widely used, as is the technology for insertion of the cover sheets. The primary technical challenge is the handling and conveyance of the carton/envelope through the cartoning equipment. The large apertures cut into the carton blank significantly reduce the rigidity of the carton and the surface area available handling machanisms	Digital printing technology is relatively new. Although it is gaining significant acceptance for document printing, its use in printing packages, particularly folding cartons, is very limited. A significant issue involves cutting, folding and gluing cartons after printing. In this case the use of a standard carton blank and gluing on the cartoner minimizes the risk. Another technical risk is the ability to shrink wrap, particularly for packages produced with dry toner technology. Dry toners are bonded to the print substrate with heat. Exposure to heat in the shrink tunnel can change the appearance of the toners. There are technical fixes for this but some experimentation would be needed to make the process work.

Table 14 - Technical Risk Comparison Table

	Pre-printed Offset Cartons	*Thermal Transfer Coder printing*	*Windowed Carton with Cover Sheets*	*Digitally Printed Cartons*
Cost	Best for runs over 5000 Prohibitive for runs under 5000	Slightly higher than offset at all volume levels	More expensive than offset for large runs and more expensive than digital printing for short runs	Best for runs under 5000
Print Quality	High	Medium	High	High
Flexibility	Medium	Low	High	High
Process Compatibility	High	Medium	Medium	High
Technical Risk	Minimal	Low	Moderate	Moderate
Overall Rating	**Best choice for standard items** – *low cost for large runs and excellent print quality, but expensive for short runs and lead times limit flexibility*	Provides limited customization and no cost advantages for this application	Provides high flexibility and excellent print quality, but cost of cartons and cover sheets is higher than other options at all volume levels	**Best choice for small volume or short lead time items** – *low cost for short runs with good print quality and very flexible, but expensive for larger runs and limited color*

Table 15 - Overall Comparison Summary Table

V. Summary, Conclusions and Recommendations

Summary of Findings

The results of this study demonstrate that there are several potential means of on-line application of graphics and variable information that can be cost competitive at low volumes and provide high quality graphics. In particular, the use of digital envelope printing provides a high level of flexibility, rapid turn-around and low cost for small volume runs (under 5000 units).

Conclusions

These results support the hypothesis that on-line printing/graphics application for low volume, customized packages facilitate packaging postponement by providing high quality graphic presentation with short lead times at a total cost competitive with traditional off-line envelope printing. If potential cost savings related to finished goods inventory were included in the analysis, cost competitiveness for digital printing improves significantly and becomes competitive at higher volume levels.

Recommendations

These results support the implementation of an approach which combines the use of offset lithographic printing of cartons with run sizes of 5000 units and more with the use of digital printing of cartons with run sizes of less than 5000 units. As digital printing technology develops and continues to come down in cost, the volume levels at which digital printing is cost competitive will increase.

In this case study, the total monthly order volume for those items with monthly volumes of less than 5000 units is about 60,000 units (720,000 units annually). These volumes would not be adequate to support the installation of a digital press and related carton cutting equipment at the packaging line. This does not necessarily eliminate the possibility of using digital printing to produce low volume cartons.

Several options exist to support digital carton printing. A partnership could be established with a local printer to perform the printing on a digital press and die cutting. This option is particularly effective if the same printer is doing the large run offset printing as well since they could utilize the same carton die cutting process. This would still provide the benefits of digital printing (short lead times and lower cost for small volumes) to the packager, but the press could be better utilized by a printing company than by the packager.

Alternatively, the digital press and die cutting equipment could be installed in a packaging area designed for short production runs for multiple product lines. The combined volumes from the different product lines would be adequate to fully utilize the equipment. In this sort of environment the cutting equipment would have to be very flexible. Digital laser cutting equipment might be appropriate.

Future Research

This study answers the question of whether on-line package customization can be cost effective. Several questions are raised that require additional research beyond the scope of this study.

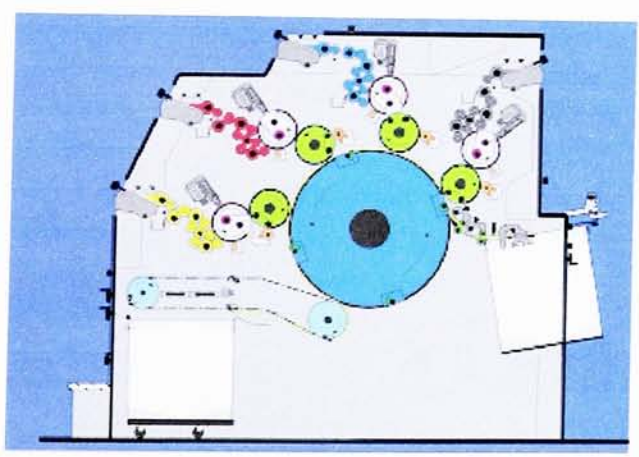
- Many of these technologies are still developing. This study demonstrates that processes such as digital printing and laser cutting are capable of producing high quality cartons at competitive cost in low volumes. There are few existing installations that might be the basis for judging the reliability of these technologies Further investigation is needed to confirm that these technologies are robust and cost effective in true production environment.
- This focus of this study was materials, labor and other costs directly associated with packaging. Postponement, using digital printing technology represents an opportunity for significant cost savings which are not directly tied to packaging materials or operations. Potential cost savings related to reduced finished goods inventories can be very

significant depending on the number of variations which are offered. Detailed evaluation of this opportunity is needed.

- The use of cover sheets in this study assumed the use of offset lithography for printing the cover sheets. Under this assumption, the concept was not cost competitive with the current custom envelope process. Further investigation is needed to determine whether this option would be cost effective if the cover sheets were printed digitally to improve the economics of small runs or if larger runs of cover sheets were printed and carried in inventory.

Appendix A – Digital Printing Presses

Heidelberg Quickmaster DI-46



Press

Formats

Largest sheet	480 x 340 mm (18 1/8" x 13 3/8")
Smallest sheet	140 x 89 mm (5 1/2" x 3 1/2")
Maximum image area	450x330 mm (17 3/4" x 13")
Gripper bite	10 mm (13/32")
Stock thickness	0.06 – 0.30 mm (0.0024" to 0.012")

Waterless offset plates

Material	Polyester
Supply roll	Sufficient for approx. 35 jobs

Speed

Maximum	10,000 sph
Minimum	3,500 sph
Crawl speed	500 rph

Direct Imaging

Laser diodes	16 IR laser diodes per PU

DI Controller

Processor	Pentium
Hard disk	1 GB as page buffer for bitmap data

Blankets

Length x width	Metal-edged, 555 x 337 mm
Thickness	1.95 mm (0.077")
Blanket cylinder undercut	2.3 mm (0.091")

Inking systems

Form rollers	3
Total rollers	12

Pile heights

Feeder	490 mm (1'7 1/4")
Delivery	450 mm (1'5 3/4")

Environmental emissions

Noise as per DIN 45635	< 80 dB(A)
Heat dissipation	Depending on power requirement

Dimensions

Press (LxWxH)	2.45 x 2.55 x 1.90 m (8'1/2" x 8'4 1/2" x 6'3 1/2")
Press height with raised guard	2.19 m (7'2 1/4")

Weights

Complete press with accessory	3,800 kg (8,378 lbs.)
Median static floor load	6,350 N/m² (133 lbs./sq.ft.)
Maximum static surface pressure	120 N/cm² (174 lbs./sq.ft.)
Dynamic share of loading	<3%

Power requirements

At 50/60 cycles	10.5 kW
Electrical fusing at 380 V	32 A
Electrical fusing at 220-240 V	50 A

Recommended operating environment

Temperature	20°C to 25°C (68°F to 77°F)
Relative humidity	50±5%

Figure 23 - Heidelberg Quickmaster DI-46

Indigo Omnius

Specifications

Image Size	Maximum frame size 308mm x 437mm (12.1"x17.2")
Cut Off Length	Digital variable cut off 280mm - 437mm (11"-17.2")
Roll Size	Nominal 320mm (12.6"), 3" or 6" core, up to 400mm (15.7") diameter
Thickness	10 microns to 300 microns
Throughput	1000 four-colour frames/ 437 linear meters per hour
Resolution	800 dpi, 200 lpi, with High Definition Imaging™
Data Rate	Up to 600 Mbit/sec
Input Formats	Adobe PostScript® 3, Scitex HandShake™
Options	Six colour printing High Definition Imaging (HDI™) Enlarged storage capacity Enlarged on-line memory Electronic collation E-RIP™ processor Yours Truly® Personalization Retraction capability

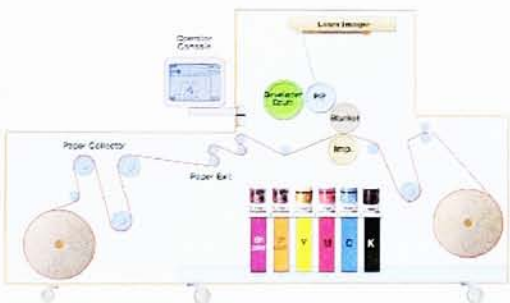
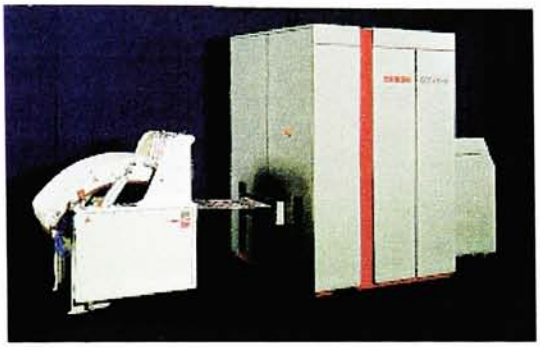


Figure 24 - Indigo Omnius

Xeikon DCP/50-SP



DCP/50-SP for paperboard packaging

Print Technology

- LED array based dry toner electrophotography
- Process Colors: Cyan, Magenta, Yellow and Black
- Clean and environmentally friendly press operation

Print Media

- Web fed
- Media width: 500 mm (20")
- Paper: 60 - 300 g/m² (40 lb text to 90 lb cover)
- Paperboard: FBB, SBB
  up to 300g/m²

Press Throughput

- Web speed: 7.35 m/min (24 ft/min)
- Throughput: 680 sheets 50 x 70 cm per hour

Imaging

- Spatial resolution: 600 dpi with variable dot density
- Imaging width: 495 mm (19.7")

Output Unit

- Cut sheet output
- Output jogger

Dimensions (H x W x D)

- Print engine: 2280 mm x 1620 mm x 1760 mm
  (89.7" x 63.8" x 69.4")
- Paper input unit: 230 mm x 960 mm x 1005 mm
  (47.2" x 38.6" x 39.5")
- Jogger: 590 mm x 2480 mm x 1320 mm
  (23" x 98.6" x 23.8")
- Digital Front End: 2150 mm x 2480 mm x 1420 mm
  (9.7" x 96.7" x 51.5")

Power Requirements

- 3 Phase
- 11.5 kW at peak load

Compliances

- CE, GS, CB, UL, cUL

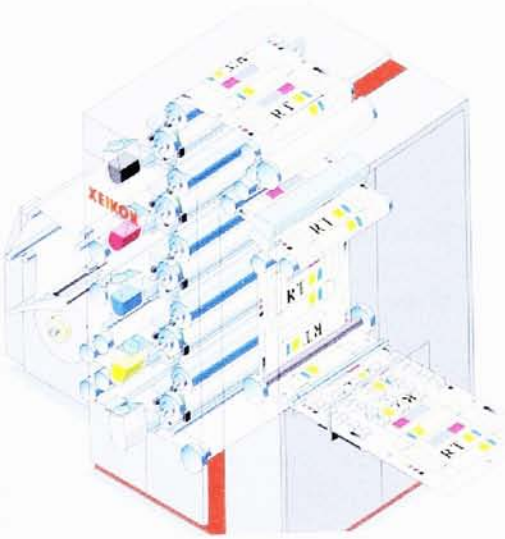


Figure 25 – Xeikon DCP/50-SP

Appendix B - Xeikon Cost Calculator Spread Sheet

XEIKON

DRIVING DIGITAL COLOR PRINTING

DCP/50D and DCP/32D Cost Calculator

May 8, 2000

Job description

Job title	Folders		
Quantity	1,000	documents	*Documents are complete final products, e.g. a book, a report, a poster, a set of datasheets, etc.*
Signatures per unit or document	1	signatures	*Signatures are the individual sheets of print media which come off the press. A document may consist out of several signatures. A single signature can contain several pages, printed double or single sided.*
Single or double sided printing	Single		
Predefined signature formats	Custom		

Or custom signature format (select 'Custom'):

Full height (H) (incl. bleed margins)	22.00	inches
Full width (W) (incl. bleed margins)	16.00	inches
The job will be printed on	DCP/50D	

Selected signature format

Full height (H) (incl. bleed margins)	**22.00**	inches
Full width (W) (incl. bleed margins)	**16.00**	inches

The defined job will fit on the selected press.

Signature summary:

With the current settings, the 1000 sample(s) of 'Folders' will require 1000 signatures in total, printed single sided.
To optimize media usage and production time, signatures will be positioned with their width across web.

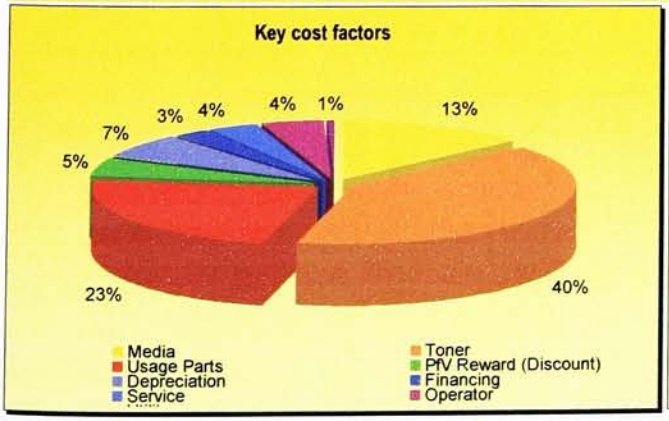
Toner Coverage and print media

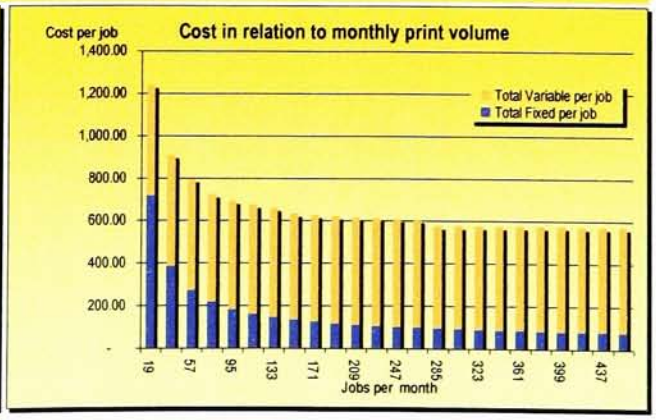
Document type	Solid background	
Average toner coverage	**145%**	

Print media type	Uncoated	
Print media, price per 100 running foot	5.00	US $ per 100 running foot
Expected selling price		US $ in total for the job

Summary - Total Cost of Ownership

For this job	**614**	US $	Per unit / document	**0.61**	US $ per Folders
Profit margin	**#DIV/0!**				





XEIKON

DRIVING DIGITAL COLOR PRINTING

Total Cost of Ownership Calculation - DCP/50D

May 8, 2000

Job name: Folders

1. Variable cost — 80%

a. Print Media: Uncoated — 18%

Printed length	1,833.3	feet
Media loss at start-up	-	feet per start-up
Total media length	1,833.3	feet
Media cost per running foot	0.05	US $ per foot
Media cost for the total job	**91.67**	**US $ per job**

b. Toner — 53%

Total printed surface	227.10	sqm
CMYK toner price per gram	0.17	US $ per gram
Toner consumption	1,662.95	gram
CMYK toner cost for the total job	**275.30**	**US $ per job**

c. Usage parts (see separate calculation sheet) — 30%

Usage parts per meter	0.28	US $ per meter
Usage parts cost for the total job	**156.71**	**US $ per job**

d. Print for Volume Reward - Cost Reduction — -6%

Double Platinum	0.14	US $ per sqm
Print for Volume Reward on this job	**32.87**	**US $ per job**

Total variable costs per job **490.81** **US $ per job**

2. Fixed cost — 20%

Print Speed	1,440	feet per hour
Time required for this job	**1:16**	
Hourly rate	96.68	US $ per hour

Depreciation	**47.53**	**US $ per hour**	39%
Financing	**17.11**		14%
Service	**24.50**		20%
Operator	**29.71**		24%
Utility	**4.24**		3%

Total fixed cost per job **123.09** **US $ per job**

3. Total cost for 'Folders'

613.89 **US $ per 1000 Folders**

Total cost per foot	**0.33**	**US $ per foot**
Total cost per unit / document	**0.61**	**US $ per Folders**

XEIKON
DRIVING DIGITAL COLOR PRINTING

DCP/50D and DCP/32D Cost Calculator

Prices

May 8, 2000

Local currency	US $

Usage parts	DCP/32D US $ per unit	DCP/50D US $ per unit
Developer CMYK	353.00 1.70 kg	477.50 2.30 kg
OPC drum (standard)	418.00 pce	585.50 pce
OPC drum (encoder)	479.00 pce	645.50 pce
Cleaning unit brush	79.00 pce	89.00 pce
Cleaning unit high-voltage roller	76.00 pce	132.00 pce
Cleaning unit scraper blade	5.70 pce	8.20 pce
Drum cleaning felt	12.50 pce	17.90 pce
Scorotron grid	12.40 pce	14.90 pce
TED Corotron wire	8.00 pce	8.00 pce
Filter cartridge for DURA humidifier	15.00 pce	15.00 pce
Air filter	119.00 pce	119.00 pce
Ozone filter assembly	225.00 pce	225.00 pce
GEM nip roller	124.00 pce	149.00 pce
Cutter knife	744.00 pce	803.00 pce
Other usage parts	0.02 per m	0.02 per m

Consumables	DCP/32D US $	DCP/50D US $
Toner (CMYK)	132.44 bottle (800 gram)	132.44 bottle (800 gram)

Engine specifications	DCP/32D	DCP/50D
Width of substrate web	12.6 inches	19.7 inches
Imageable width	12.08 inches	18.70 inches
Press speed	24 feet/min	24 feet/min

Fixed Cost Parameters	DCP/32D	DCP/50D
Cost of machine	401,000 US $	560,000 US $
Depreciation period	5.00 years	5.00 years
Annual depreciation	**80,200** US $	**112,000** US $
Proportion financed (%)	90%	90%
Interest rate (%)	8.00%	8.00%
Annual interest	**28,872** US $	**40,320** US $
Service contract	50,160 US $	57,720 US $
Employment of operator (per shift)	25,000 US $	35,000 US $
Shift premium	0%	0%
Total operator employment (all shifts)	50,000 US $	70,000 US $
Heat, light, power, rent, etc.	10,000 US $	10,000 US $
Service / Operator / Utility	**110,160** US $	**137,720** US $
Total annual fixed cost	**219,232** US $	**290,040** US $

Available hours p.a.	DCP/32D	DCP/50D
Weeks per year	50 weeks	50 weeks
Hours per week per shift	40 hours	40 hours
Shift operation	2.0 shift	2.0 shift
Working hours per week	80 hours	80 hours
Utilisation factor (%)	75%	75%
Available hours p.a.	**3,000** hours per year	**3,000** hours per year
Average monthly volume	**525,000** A4 eq.	**750,000** A4 eq.

Hourly rate	DCP/32D	DCP/50D
Hourly rate	**73** US $ per hour	**97** US $ per hour

Print for Volume Reward	DCP/32D	DCP/50D
Average quarterly printed media	105,352 square meter	164,717 square meter
Print for Volume Qualification	**Platinum**	**Double Platinum**
Print for Volume Reward	11,920 US $ per quarter	23,839 US $ per quarter
Print for Volume Reward	**0.11** US $ per sqm	**0.14** US $ per sqm

Appendix C – Vendor Supplied Digital Printing Performance Comparisons

Cost Comparison Charts

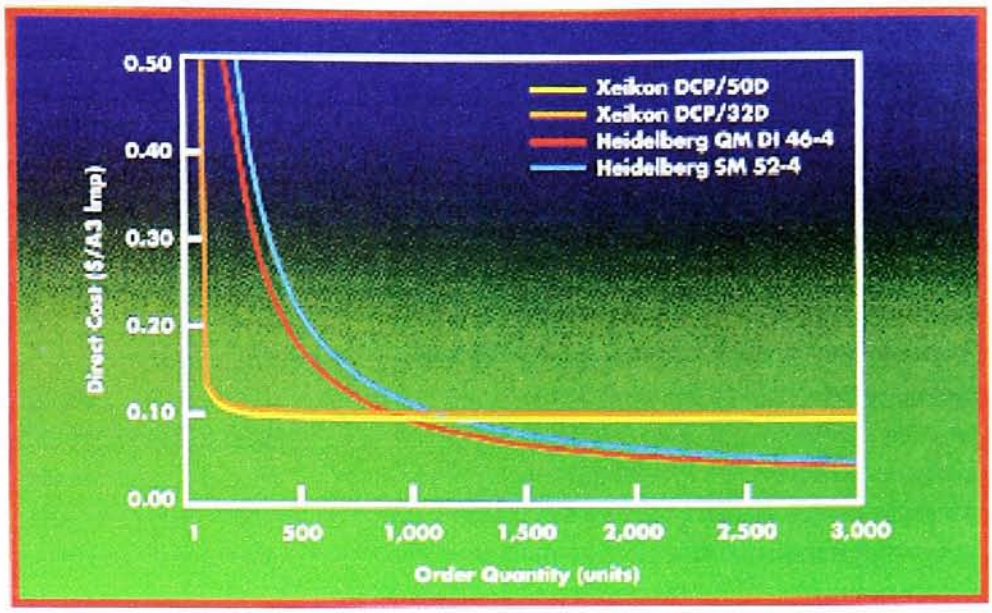


Figure 26 – Cost Versus Run Length (Source: Xeikon)

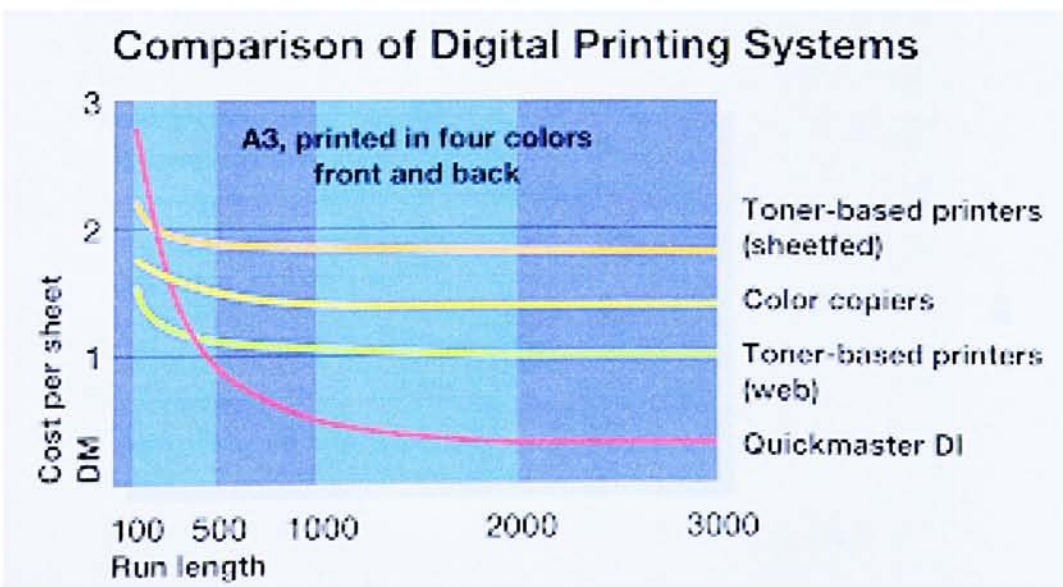


Figure 27 – Cost Versus Run Length (Source: Heidelberg)

Productivity and Quality Comparison Charts

Figure 28 – Productivity Versus Run Length (Source: Xeikon)

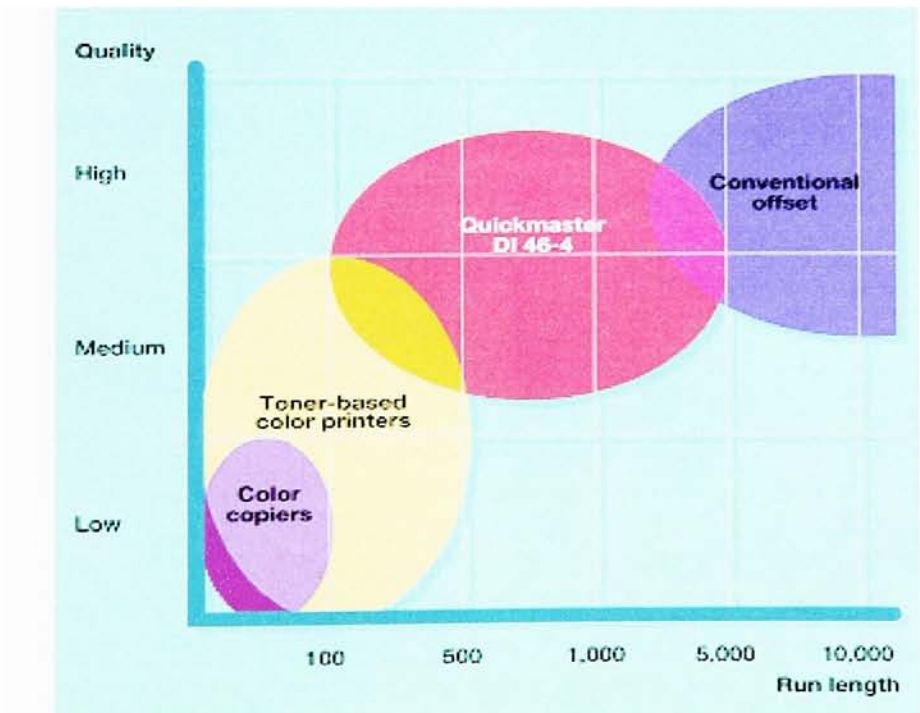


Figure 29 – Market Position for Different Print Technologies (Source: Heidelberg)

Appendix D – Thermal Transfer Coder Printers

Markem SmartDate

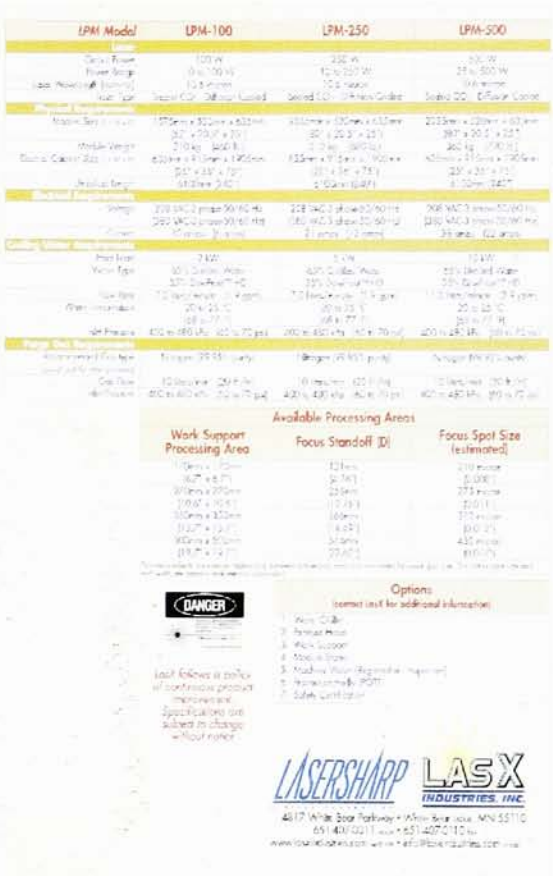
Figure 30 – Markem SmartDate Printer

Weber Easyprint

Figure 31 – Weber Easyprint Printer

Appendix E - Digital Laser Cutting Equipment

LaserSharp Digital Converting System



LPM Model	LPM-100	LPM-250	LPM-500

Available Processing Areas

Work Support Processing Area	Focus Standoff (D)	Focus Spot Size (estimated)

DANGER

Options

LASERSHARP LASX INDUSTRIES, INC.

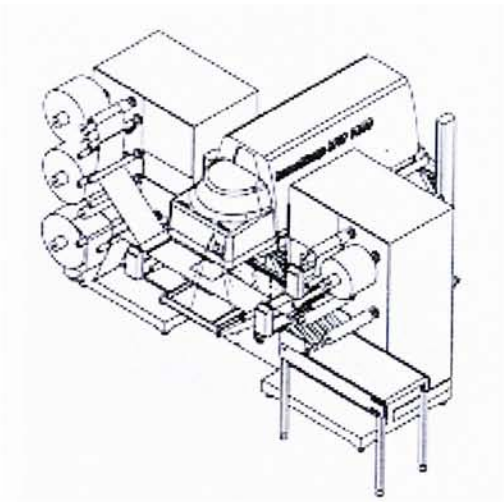


Figure 32 - LaserSharp Digital Converting System

Appendix F – Automated Sheet Counting Equipment

Streamfeeder ST1250 Universal Friction Feeder

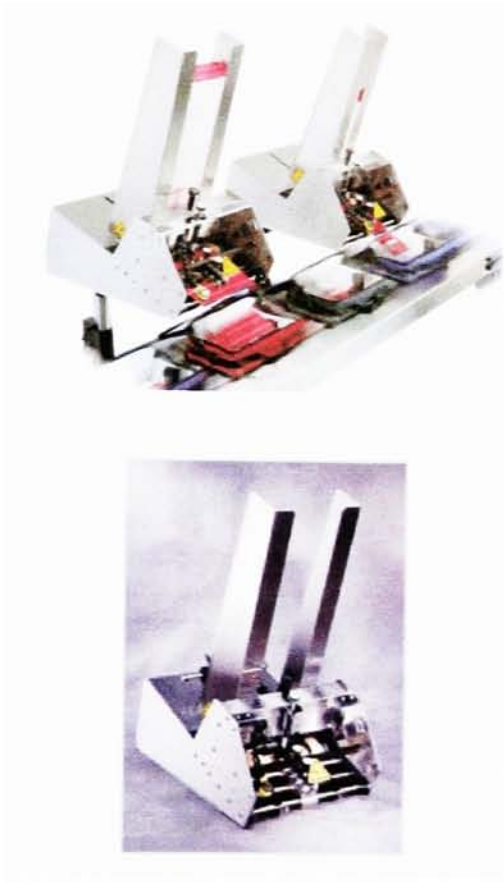


Figure 33 - Steamfeeder ST1250 Feeder

STANDARD FEATURES

OPTIONS

SPECIFICATIONS

Maximum Product Size:		
Minimum Product Size:		
	Optional:	
Thickness Range:		
Belt Speed:		
Feed Rate:	Batch mode:	
	One shot mode:	
Hopper Capacity:		
Display:		
Keypad:		
Drive:		
Power Input:		
Current:		
Sensors:		
Construction:		
Communication:		
Flight Skips:		
Batch Size (batch mode only):		
Time Delays:		
Feed Triggers:		
Acceleration:		
Slow Down (batch mode only):		
Overall Dimensions:		
Weight:		
Certifications:		
Warranty:		

Bibliography

"All About Thermal Transfer". Paxar. 1998. 3 pages. Online. Available: http//www.iimak.com/thermal.html. 22 October 1999

Anderson, David L., Britt, Frank E. and Donavon J. Favre, "The Seven Principles of Supply Chain Management", *Logistics Magazine*, 1997: 12 pages. Online. Available: http//www.manufacturing.net/magazine/logistics/archives/1997/scmr/11princ.html. 2 June 1999.

Boyle, Edward. "Lasers are on the Cutting Edge, Digitally Speaking". *Paper Film Foil Converter Magazine*. April 1999. Pp. 14 – 15.

Davis, Stanley M., *Future Perfect*, Addison-Wesley Publishing Co. Inc, Reading, Mass.; 1987.

Gilmore, James H., and B. Joseph Pine, "The Four Faces of Customization", *Harvard Business Review*, January-February 1997. Pp. 91 – 101.

Gooley, Toby B., "Mass Customization: How logistics makes it happen". *Logistics Magazine*, 1998: 4 pages. Online. Available: http//www.manufacturing.net/magazine/logistics/archives/1998/log0401.98/04scm.html. 2 June 1999.

Graman, Gregory A. and Michael J. Magazine, "An Analysis of Packaging Postponement", Unpublished Master's Thesis: Department of Quantitative Analysis and Operations Management, College of Business Administration, University of Cincinnati. Cincinnati, Ohio; 1999.

"Key Driver's for the Future of Manufacturing", Rockwell International. 1997: 3 pages. Online. Available: http//www.ab.com/events/choices/key.html. 28 April 1999.

Pine, B. Joseph II, *Mass Customization: The New Frontier in Business Competition*, Harvard Business School Press. Boston. Mass. 1993.

"Postponement Systems: Waiting to the last minute is a virtue". *Modern Materials Handling*, May 1998. Pp. 27 – 28.

Reynolds, Pat. "Shipper Strategies for a Global Marketplace" *Packaging World Magazine.* June, 1998. 7 pages. Online. Available: http//guanabana.com/packworld/D.../14261926941473.html. 17 May 1999.

Toberson, Eric. "Mass Customization: As You Like It" *CIO Enterprise Magazine.* February 15, 1998. 8 pages. Online. Available: http//www.cio.com/archive/enterprise/021598_mass_content.html. 5 May 1999.